



THE UNIVERSITY OF QUEENSLAND  
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**An investigation of sustainable spinifex-harvesting and knowledge revival: A case  
study in northwest Queensland**

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*A thesis submitted for the degree of Master of Philosophy at  
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## **Abstract**

*Triodia pungens*, a resinous spinifex grass, is proving to be a potential future bio-resource for the building industry and remote Aboriginal communities are likely to benefit from any new sustainable spinifex-harvesting industry. The Indjalandji-Dhidhanu people in the Camooweal region are an industrious Aboriginal community who would like to undertake spinifex harvesting, but questions such as when and how often should they harvest, and whether it would be sustainable in the long term, were critical to a successful spinifex industry. This thesis examines these questions through experiments, and a literature review of spinifex fire ecology and past Indigenous ecological knowledge of spinifex. It is argued that a lack of scientific studies in this region and an oversight by ethnographers to record how Aboriginal people selected spinifex plants for resin and fibre extraction both contribute to a lack of contemporary spinifex knowledge. The scientific literature however, argues that fire, heat and smoke are necessary to stimulate seed production and resprouting from plant crowns. As such, it was largely unknown how or whether spinifex would regrow after harvesting in the absence of heat and smoke. Gaps also appeared in the resin and fibre production, and flowering literature and it was unknown when spinifex produced resin and if flowering occurred annually in the region.

In an attempt to examine these questions, fire and harvesting experiments were conducted within a spinifex/snappy gum shrubland near Camooweal, north-west Queensland. The aim of this research was to develop an understanding of spinifex ecology and through this, develop knowledge of harvesting practices and spinifex resin-cycles and fibre production, which can underpin future commercial applications of sustainable spinifex-harvesting and Indigenous ecological knowledge revival in the study area.

This study monitored post-fire and post-harvest spinifex regeneration from 2009 to 2011. When *Triodia pungens* was intensively burned and harvested to ground level, spinifex hummocks were killed outright. Spinifex recovery is entirely by seedling regeneration and seedling numbers increase after the first wet season but taper off as mature hummock numbers increase in size. Ancillary harvesting tests found that partial removal of hummocks provides living plant tissue for spinifex to recover by rapid tiller production and subsequent stoloniferous regeneration. That is, many tillers (prop-roots) and stolons emerge from the host plant to form a new hummock within two wet seasons. Analyses of daily growth rates identified that removing sizeable portions of hummocks in

the dry season provides the best results. This has important implications for spinifex regeneration where spinifex recovery is crucial to sustainable harvesting, and particularly for maximum spinifex resin and fibre production. This holistic strategic approach encourages the advancement of knowledge of spinifex and provides a vehicle for developing a successful spinifex industry run by Aboriginal people.

## **Declaration by author**

This thesis is composed of my original work, and contains no material previously published or written by another person except where due reference has been made in the text. I have clearly stated the contribution by others to jointly-authored works that I have included in my thesis.

I have clearly stated the contribution of others to my thesis as a whole, including statistical assistance, survey design, data analysis, significant technical procedures, professional editorial advice, and any other original research work used or reported in my thesis. The content of my thesis is the result of work I have carried out since the commencement of my research higher degree candidature and does not include a substantial part of work that has been submitted to qualify for the award of any other degree or diploma in any university or other tertiary institution. I have clearly stated which parts of my thesis, if any, have been submitted to qualify for another award.

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**Publications during candidature**

None

**Publications included in this thesis**

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## **Contributions by others to the thesis**

### **Australian Research Council (ARC)-funded project (DP0877161)**

- Travel and support for fieldwork at Camooweal, Queensland.

### **Commonwealth Scientific and Industrial Research Organisation (CSIRO)**

- Development of linear model and analysis of spinifex growth rates was completed by Dr Ryan McAlister, a systems research scientist with Commonwealth Scientific and Industrial Research Organisation (CSIRO), Ecosystem Sciences, Brisbane, Queensland.

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- Supply of machinery and field equipment.
- Assistance by Aboriginal Trainees and Supervisor to conduct the fire and harvesting components of the fieldwork.
- Meals and accommodation.

**Statement of parts of the thesis submitted to qualify for the award of another degree**

This thesis has not been used for another award.

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sustainable harvesting, Indigenous ecological knowledge revival, spinifex regeneration, hummock grasslands, fire, seedlings, rapid tiller production,

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## **Abbreviations**

ARC	Australian Research Council
DSB	Dry Season Burn
DSH	Dry Season Harvest
IEK	Indigenous Ecological Knowledge
Spinifex	<i>Triodia pungens</i>
WSB	Wet Season Burn
WSH	Wet Season Harvest

## **Chapter 1**

### **Investigating Sustainable Harvesting**

#### **Introduction**

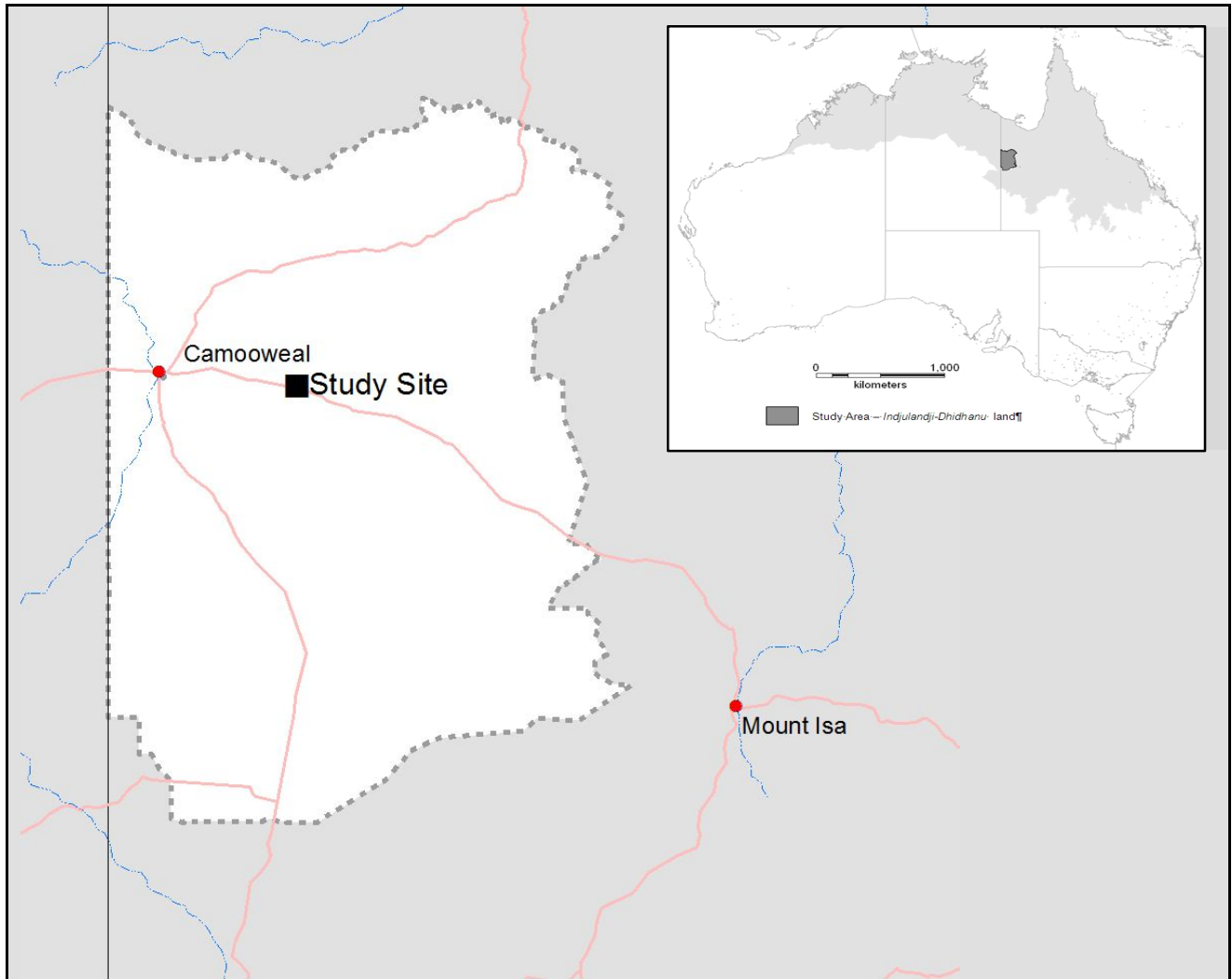
This thesis is concerned with sustainable spinifex-harvesting near Camooweal in northwest Queensland, a region that has been the focus of spinifex (fibres and resin) bio-engineering research for its potential commercial uses in the building industry. The region is dominated by *Triodia pungens*, a resinous spinifex species that has been used by Aboriginal people for thousands of years to produce a thermoplastic bonding agent and to clad seasonal living structures. Traditional knowledge surrounding spinifex harvesting in the region is undocumented but in the last four decades however, ecological research across northern and Central Australia has focused on post-burn spinifex regeneration. This situation means that there is considerable reliance (and perhaps over-reliance) on previous fire ecology studies and the ethnographic literature in attempting to discern how spinifex might regenerate if subject to commercial harvesting. It is also important to determine the best time of year for extracting resin or harvesting spinifex fibre and thus gaining empirical knowledge of its post-harvesting regeneration for developing a sustainable spinifex industry.

The primary aim of this thesis is to develop an understanding of spinifex ecology such that harvesting practices and knowledge of spinifex resin-cycles and flowering can underpin Indigenous ecological knowledge revival and future commercial applications of sustainable spinifex-harvesting in the study area.

The key objectives of the thesis are to:

1. Examine Indigenous knowledge about spinifex in the study region and inland Australia.
2. Investigate previous ethnographies with the intention of knowing more about Indigenous knowledge of spinifex management.
3. Describe key characteristics of a local spinifex species, *Triodia pungens*, from field experiments provide an insight into previous Indigenous Ecological Knowledge systems.
4. Integrate the above information and suggest how spinifex can be sustainably managed and included in hybrid economies for Aboriginal communities.

The study site is located approximately 35 kilometers east of Camooweal and approximately 150 km west of Mount Isa on the Barkly Highway (Fig. 1). It lies within the spinifex grasslands in the Indjalandji-Dhidhanu tribal area.



**Figure 1.** Map showing the study site east of Camooweal, Queensland beside the Barkly Highway and within the Queensland portion of Indjalandji-Dhidhanu tribal lands (dotted outlined).



## Spinifex (*Triodia pungens*)

The genus *Triodia* R. Br., or 'spinifex', is endemic to Australia and consists of 69 species<sup>1</sup>. *Triodia* species are long-lived, hummock-forming, and mostly stoloniferous (a creeping horizontal stem or runner that takes root at various intervals) perennials that grow up to 2 m high and 6 m in diameter<sup>2</sup>. Spinifex comprises compact and symmetrical, loose or irregular or ring-forming hummocks with peripheral growth and dying from the centre outwards. The leaves are tight-folding (or rolled), needle-shaped and xeromorphic (i.e. have the ability to store water in leaves and stems) and are highly lignified (able to turn woody). In 26 species, leaves sometimes secrete a pungent sticky resin probably to reduce moisture loss during hot dry days<sup>3</sup>. *Triodia pungens* is the most commonly occurring and best known of these species, its leaves containing unique resin-producing cells<sup>4</sup>. Spinifex resin secretes from the stomatal grooves (pores in the leaf epidermis) on the adaxial (upper) leaf surface and grooves near the midrib and flows down the leaf to its base, forming a whitish granular substance as it dries on the plant<sup>5</sup>. The dried resin was extracted by Aboriginal people and used in their material culture<sup>6</sup>.

## Background

This study is one aspect of the Australian Research Council (ARC)-funded project entitled "Towards Novel Biomimetic Building Materials: Evaluating Aboriginal & Western Scientific Knowledge of Spinifex Grasses" (DP0877161), led by Chief Investigator Professor Paul Memmott. The broader project involves bioengineering of the physical properties of both the fibre and resin of spinifex to produce many new products including, 1) a nano-fibrillated cellulose; 2) a blend of spinifex and other materials to create a

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<sup>1</sup> Gamage, H., Mondal, S., Wallis, L., Memmott, P., Martin, D., Wright, B., and Schmidt, S. (2012). Indigenous and modern biomaterials derived from *Triodia* ('spinifex') grasslands in Australia. *Australian Journal of Botany*, Vol. 60: 114.

<sup>2</sup> Lazarides, M. (1997). A Revision of *Triodia* including *Plectrachne* (*Poaceae*, *Eragrostideae*, *Triodiinae*). *Australian Systematic Botany*. Vol. 10: 381.

<sup>3</sup> Jacobs, S. (1992). Spinifex (*Triodia*, *Plectrachne*, *Symplectrodia* and *Monodia*: *Poaceae*) in Australia. In Chapman, G. P. (Ed.), *Desertified Grasslands: Their Biology and Management*. Academic Press, London. 49.

<sup>4</sup> Gamage, H., Mondal, S., Wallis, L., Memmott, P., Martin, D., Wright, B., and Schmidt, S. (2012). Indigenous and modern biomaterials derived from *Triodia* ('spinifex') grasslands in Australia. *Australian Journal of Botany*, Vol. 60: 114.

<sup>5</sup> Jacobs, S. (1992.) Spinifex (*Triodia*, *Plectrachne*, *Symplectrodia* and *Monodia*: *Poaceae*) in Australia. In, Chapman, G. P. (Ed.), *Desertified Grasslands: Their Biology and Management*. Academic Press, London. 49.

<sup>6</sup> Pitman, H. and Wallis, L. (2012). The point of spinifex: Aboriginal uses of spinifex grasses in Australia. *Ethnobotany Research & Applications*. Vol. 10: 109-131.

biocomposite material (to replace dangerous chemicals that normally used in e.g. particle board); 3) a varnish to repel termites in timber and; 4) a product for screening ultraviolet light<sup>7, 8</sup>. The current research questions that need to be answered encompass an understanding of spinifex recovery and growth rates following a commercial harvest, and the plants' resin and flowering cycles to enhance our knowledge of the ecology of this species.

Prior to the commencement of this study no spinifex-harvesting research had been conducted in the region or indeed anywhere in Australia. If harvesting is to be sustainable, spinifex will need to regenerate from seed production and/or resprout from basal leaf crowns, and totally recover within several years. However, the management of spinifex grasslands has always been through fire. Therefore, there is a gap in the available knowledge concerning the impact of harvesting.

Previous post-fire regeneration research has shown that, after fire, spinifex regeneration begins with a thin veneer of grasses and forbs<sup>9</sup>. Seedling germination occurs under average air temperatures of 30–35° C<sup>10</sup> and more than 40 mm of rainfall, and scarification or smoke influences seed germination success rates<sup>11,12</sup>. Spinifex will also regenerate by resprouts—fresh shoots emerge from a plant crown. The Camooweal region is known to have both regenerative forms within a relatively close proximity to the other.

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<sup>7</sup> Memmott, P., Schmidt, S., Master, D., Fensham, R., and Hyde, R. (2008). Towards Novel Biomimetic Building Materials: Evaluating Aboriginal & Western Scientific Knowledge of Spinifex Grasses. Aboriginal Environments Research Centre, The University of Queensland, St Lucia, Queensland.

<sup>8</sup> Memmott, P. Hyde, R. and O'Rourke, T. (2009). Biomimetic Theory and Building Technology: Use of Aboriginal and Scientific Knowledge of Spinifex Grass. *Architectural Science Review*. Vol. 52(2): 117-125.

<sup>9</sup> Griffin, G. (1992). Will it burn – should it burn?: management of the spinifex grasslands of inland Australia. In, Chapman, G. P. (Ed.), *Desertified Grasslands: Their Biology and Management*. Academic Press, London. 63-76.

<sup>10</sup> Jacobs, S. (1992). Spinifex (*Triodia*, *Plectrachne*, *Symplectrodia* and *Monodia*: *Poaceae*) in Australia. In, Chapman, G. P. (Ed.), *Desertified Grasslands: Their Biology and Management*. Academic Press, London. 51.

<sup>11</sup> Bogusiak, A., Rice, B., and Westoby, M. (1990). Seedling emergence of hummock grasses in relation to the effects of fire. *Australian Rangelands Journal* 12(1): 25-28.

<sup>12</sup> Christian, C., Noakes, R., Slayter, R., Stewart, G., and Traves, D. (1954). Survey of the Barkly Region, Northern Territory and Queensland, 1948-49, *Land Research Series No 3*. Commonwealth Scientific and Industrial Research Organisation, Australia. Melbourne.

## The Problem

In the initial phase of the broader ARC project, researchers were optimistic that *T. pungens*—the most commonly occurring spinifex species around Camooweal—could be sustainably harvested for commercial purposes to develop a spinifex fibre and resin use industry, e.g. insulation cladding for housing, and applying a solution of resin-derived product to raw timbers for termite controls. However, the limitations of existing scientific research on spinifex-harvesting and of extant IEK research of resin production cycles raised questions about harvesting techniques and timing, spinifex regeneration, growth rates and resin production cycles. The indicators of sustainable spinifex-harvesting would be that post-harvesting regeneration and growth rates at a minimum replicate those of post-burn regeneration. If these conditions were not met, harvesting would pose ecological threats (loss of habitat) and environmental impacts (e.g. erosion), which would negate any possibility of commercial harvesting.

A further consideration is that the relationships between geographical location and spinifex regrowth mechanisms are not clear; as such, knowing rainfall levels, the spinifex species, and the local geography does not inform us as to how spinifex regenerates<sup>13</sup>. What is known though, is that spinifex regenerates after fire by both seedling and resprouts, and regrowth can vary both spatially and within the same species. Therefore, spinifex regeneration after harvesting is unknown—factors such as heat and smoke are argued to be necessary to stimulate seed production and resprouting from basal hummock crowns. Developing a better understanding of when spinifex plants produce resin and flower (which produces only a small number of seeds) will thus further inform the development of spinifex management strategies for sustainable harvesting practices. From this, it may also be possible to assist Indjalandji-Dhidhanu people of the Camooweal region to develop an effective spinifex management program.

Prior to the commencement of this study, Bowman and Prior undertook fire-ecology studies in the Tropical Savanna<sup>14</sup>. They concluded that Aboriginal fire management influenced the vegetation structure and fire was an important tool in managing woodlands

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<sup>13</sup> Rice, B. and Westoby, M. (1999). Regeneration after fire in *Triodia* R. Br. *Australian Journal of Ecology*. Vol. 24: 563.

<sup>14</sup> Bowman, D. and Prior, L. (2004). Impact of Aboriginal landscape burning on woody vegetation in *Eucalyptus tetradonta* savanna in Arnhem Land, northern Australia. *Journal of Biogeography*. Vol. 31: 807-817.

and grasslands in the tropical savanna<sup>15</sup>. In the study site however, a single fire-ecology research project accounted for the extent of spinifex research<sup>16</sup>. Felderhof examined the patchiness paradigm, which is the view that discrete fires encourage greater ecological diversity and that land managers should adopt this strategy to maintain a healthier landscape<sup>17</sup>. These underlying principles lend themselves to the 'firestick-farming' paradigm that were used by Aboriginal people for many thousands of years<sup>18</sup>. Aboriginal people arguably used fire to reduce spinifex fuel loads and stimulate the regeneration of non-*Triodia* species<sup>19</sup>. Typically, many small fires were lit and allowed to burn across small areas of spinifex and create a 'mosaic' grassland at varying stages of growth, producing a diverse and productive landscape<sup>20</sup>.

## Indigenous Ecological Knowledge

IEK (also known as 'traditional ecological knowledge' (TEK)), has been a significant contributor to developing strategies for manufacturing modern materials from traditional Indigenous materials and techniques<sup>21</sup>. IEK is a language of scientific discourse, but more precisely it is grounded in the moral, ethical and spiritual world<sup>22</sup>. The term IEK refers to information passed on by oral tradition and that was never written down, except in cases where scientists and ethnographers work closely with Aboriginal people. IEK has slowly

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<sup>15</sup> Bowman, D. and Prior, L. (2004). Impact of Aboriginal landscape burning on woody vegetation in *Eucalyptus tetrodonta* savanna in Arnhem Land, northern Australia. *Journal of Biogeography*. Vol. 31: 815.

<sup>16</sup> Felderhof, L. (2007). *The fire patchiness paradigm: a case study in northwest Queensland*. PhD Thesis, James Cook University.

<sup>17</sup> *ibid.* 225.

<sup>18</sup> Jones, R. (1969). Fire-stick Farming. *Australian Natural History*. Vol. 16: 224

<sup>19</sup> Russell-Smith, J., Start, T., and Woinarski, J., (2001). Effects of fire in the landscape. In, Dyer, R., Jacklyn, P., Partridge, I., Russell-Smith, J. and Williams, D. (Eds.), *Savanna Burning Understanding and Using Fire in Northern Australia*. Darwin: Tropical Savanna Cooperative Research Centres. 29-49.

<sup>20</sup> Bliege Bird, B., Bird, D., Coddling, B., Parker, C., and Jones, J. (2008). The "fire stick farming" hypothesis: Australian Aboriginal foraging strategies, biodiversity, and anthropogenic fire mosaics. *Proceedings of the National Academy of Science of the United States of America*. Vol. 105(39): 14800

<sup>21</sup> Gamage, H., Mondal, S., Wallis, L., Memmott, P., Martin, D., Wright, B., and Schmidt, S. (2012). Indigenous and modern biomaterials derived from *Triodia* ('spinifex') grasslands in Australia. *Australian Journal of Botany*, Vol. 60: 114-127.

<sup>22</sup> Ford, J and Martinez, D. (2000). Traditional Ecological Knowledge, Ecosystem Science, and Environmental Management. *Ecological Applications*. Vol. 10(5): 1249.

been adding to an increasing ecological knowledge base<sup>23</sup> and international directives now highlight its importance to scientific research and to sustainable development strategies<sup>24</sup>.

Ecologists acknowledge that IEK and science share commonalities. Both approaches to understanding are based on observation and experimentation, which aim to understand the structure and behaviour of the physical and natural world<sup>25</sup>. In Australia, Traditional Owners and scientists have been working together to better understand the Australian landscape<sup>26</sup>. This accumulated knowledge and partnerships have resulted in a strengthening of conventional science-based frameworks and IEK is considered an important aspect of understanding Australia's ecology.

Because much IEK has dissipated in more recent years owing to removal of Aboriginal people from their traditional lands in the post-contact period, much of the pre-contact knowledge of spinifex has not been transferred to the subsequent generations. Whilst ethnographers documented how Aboriginal people obtained resin from spinifex, the process for selecting plants and/or habitats remains unclear and undocumented. These gaps pose two questions: What level of knowledge is needed to select plants for harvesting? And, are certain spinifex characteristics desirable in selecting a suitable area in which to harvest *Triodia pungens*?

## Research Design

The data presented in this thesis provide information about the regeneration of spinifex after both fire and harvesting by integrating fire and harvesting dynamics, and comparing the data with other fire regeneration studies in Australia (e.g. Rice and Westoby<sup>27</sup>). The emphasis is on assessing regeneration patterns at the local scale, and developing a conceptual model to predict responses to fire and harvesting treatments, particularly whether the presence of fire and/or absence of heat and smoke affects plant regeneration.

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<sup>23</sup> Ford, J and Martinez, D. (2000). Traditional Ecological Knowledge, Ecosystem Science, and Environmental Management. *Ecological Applications*. Vol. 10(5): 1249.

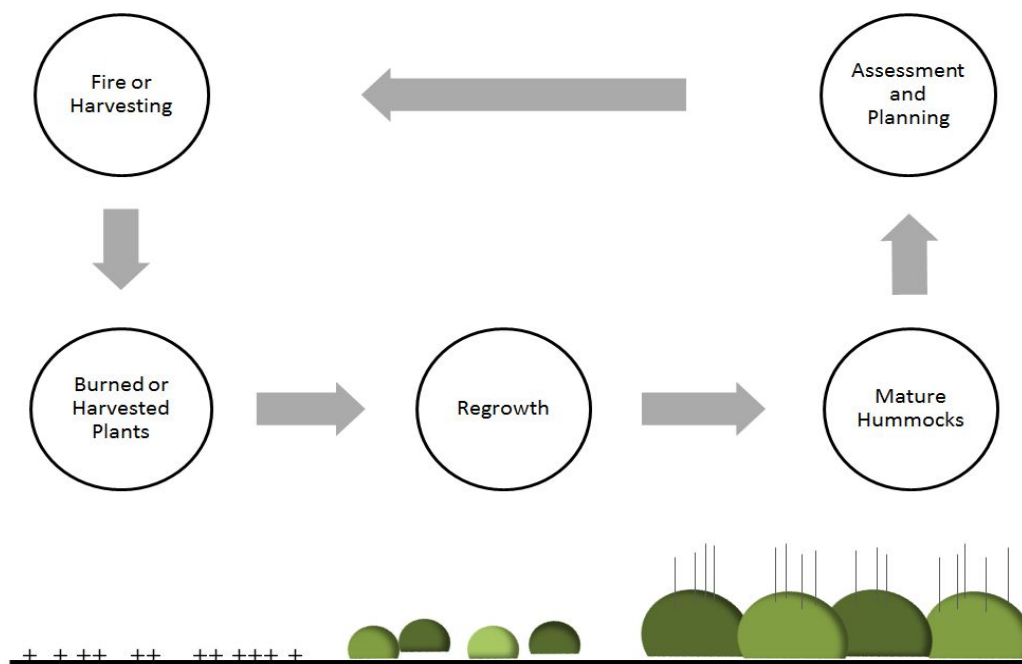
<sup>24</sup> *ibid.* 1249.

<sup>25</sup> Berkes, F, Colding, J, and Folke, C. (2000). Rediscovery of Traditional Ecological Knowledge as adaptive management. *Ecological Applications*. Vol. 10(5): 1251-1262.

<sup>26</sup> Walsh, F. and Mitchell, P. (Eds.) (2002). *Planning for Country. Cross-cultural approaches to decision-making on Aboriginal lands*. Jukurrpa Books, IAD Press, Alice Springs, Northern Territory.

<sup>27</sup> Rice, B. and Westoby, M. (1999). Regeneration after fire in *Triodia* R. Br. *Australian Journal of Ecology*. Vol. 24: 563-572.

Drawing on previous studies, Figure 2 presents a standard regeneration model showing expected regrowth/regeneration trends of a complete recovery after three wet seasons. The null hypothesis is that spinifex fails to recover after harvesting treatments as a result of an absence of scarification and smoke associated with fires. Rejection of the null hypothesis should support spinifex recovery that is similar to post-fire regeneration. In this instance, a sustainable harvesting model could be applied in the study area. The hypothesis that sets the field experimental design is for complete recovery of a harvested area following suitable climatic conditions (Fig. 2). Any delayed regeneration and failure for spinifex to regrow rejects the possibility of a sustainable harvesting model.



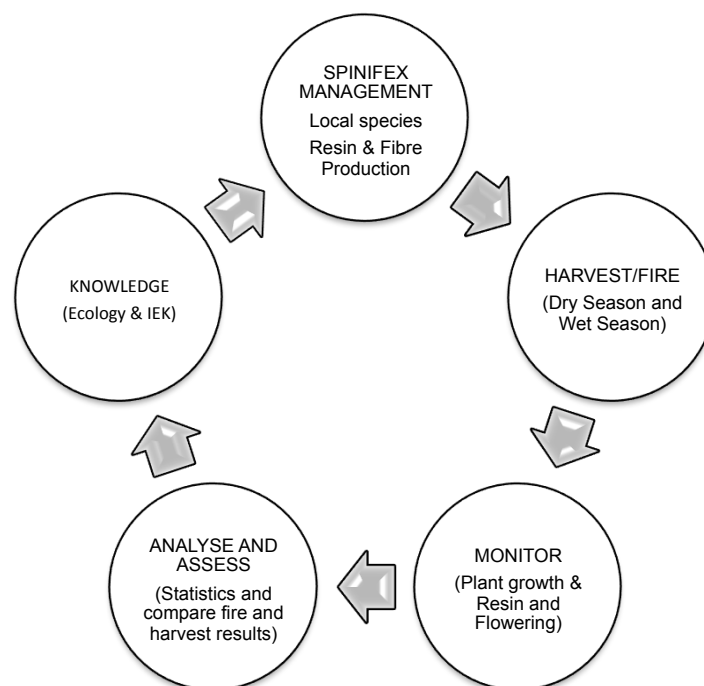
**Figure 2.** Conceptual Model: harvesting and fire treatments leading to regeneration and restoration to mature hummocks.

Resin and fibre production is also important for a sustainable harvesting model. Jacobs noted that on hot days resin flows down the leaves and stems; as the air temperature decreases, resin solidifies and cracks, allowing gas exchange<sup>28</sup>. The production of resin and subsequent drying is termed herein the 'resin cycle'.

<sup>28</sup> Jacobs, S. (1992). Spinifex (*Triodia*, *Plectrachne*, *Symplectrodia* and *Monodia*: *Poaceae*) in Australia. In, Chapman, G. P. (Ed.), *Desertified Grasslands: Their Biology and Management*. Academic Press, London. 55

Understanding resin cycles are important for planning and developing a suitable plant-harvesting strategy and economically viable and environmentally sustainable spinifex-harvesting industry. However, the exact nature of spinifex resin cycles in relation to seasonal variables is largely unknown. Further, other factors, such as the time elapsed since the last harvest, may also be important for developing a sustainable industry.

Data on fire regeneration are required for assessing the success of harvesting and monitoring growth rates, resin and fibre production, and analysing the results are important for developing knowledge of sustainable harvesting (Fig. 3). By recording plant regeneration attributes, plant growth can be tracked over time and compared between the treatments. The data analysis focuses on spinifex growth statistics, growth mechanisms and their relationship to harvesting techniques, and resin and flowering cycles and its relationship to resin and fibre production and sustainable spinifex harvesting. Growth mechanisms can be assessed in the post-treatment phase by monitoring how spinifex regenerates, i.e. seedlings or resprouts. From this information, spinifex management strategies may be implemented for this spinifex species in this region.



**Figure 3.** Thesis framework. Plans for developing a sustainable spinifex industry are to be initiated using current research knowledge, and harvesting and monitoring techniques to determine a suitable knowledge base for Aboriginal communities.

The final concern of field data collection was the timing and frequency of spinifex flowering events. It is hypothesised that flowering and seed production are linked to plant maturity, and therefore seed production is important for the maintenance of soil seed-banks and ensuring spinifex can successfully regenerate.

In summary, clearly there is a need to better understand the ecology of spinifex in regard to harvesting and previous Indigenous ecological knowledge. By strengthening our understanding of *Triodia pungens* characteristics, this should help to develop necessary strategies for sustainable harvesting practices. Links between *T. pungens* and IEK cannot be fully realised until they are investigated under field conditions. Of primary concern is the ability of spinifex to successfully regenerate and produce adequate quantities of resin or fibre for commercial applications. In addition, harvesting techniques for this species are unknown. This poses questions about developing suitable harvesting techniques and implementing sustainable harvesting strategies for the long-term. There is particular interest in assessing the current extent of IEK and incorporating it with field studies to develop sustainable *Triodia pungens* harvesting practices.

## **Aims and Significance of this Research**

The primary aim of this thesis is to develop an understanding of spinifex ecology such that harvesting practices and knowledge of spinifex resin-cycles and flowering can underpin future commercial applications of sustainable spinifex-harvesting and Indigenous ecological knowledge revival in the study area. The aim is to examine how spinifex regenerates and assess whether seasonal effects influence plant growth, resin production, and flowering events. These data are analysed to define sustainable harvesting practices and to define what could be gleaned from the data to examine IEK revival.

A secondary aim of this thesis is to identify gaps in the ethnographic literature with regard to spinifex; this may raise further questions about the viability of spinifex harvesting. Aboriginal people used fire to manage the landscape and where required, spinifex plants were harvested to extract resin or were used for constructing windbreaks and shelters, amongst other uses<sup>29</sup>. Aboriginal people administered specific fire regimes, based on their acute knowledge of plants such as their capacity to produce adequate supplies of resin at specific times of the year and in certain localities. This knowledge formed the basis for

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<sup>29</sup> Pitman, H. and Wallis, L. (2012). The point of spinifex: Aboriginal uses of spinifex grasses in Australia. *Ethnobotany Research & Applications*. Vol. 10: 109-131.



Aboriginal land management and cultural responsibilities for Country. In these situations, field research, tests, and observations might help to rebuild knowledge of spinifex ecology for the development of commercial applications in the spinifex grasslands.

The greatest potential gains from the research presented in this thesis would result in an applied commercial spinifex industry that is guided by Aboriginal people and passed on to their children. This may safeguard the community from economic disparity and reliance on government funding, and thus offer a certain level of income from profits. Gainsharing of spinifex product sales could contribute to the success of the community in the long-term.

## Thesis Structure

The key objectives of the thesis are to:

1. Examine Indigenous knowledge about spinifex in the study region and inland Australia.
2. Investigate previous scientific data and ethnographies with the intention of knowing about *Triodia pungens* and Indigenous knowledge of spinifex management.
3. Describe key characteristics of a local spinifex species, *Triodia pungens* (the term 'spinifex' is used in the following) from field experiments provide an insight in to previous IEK systems.
4. Integrate the above information and suggest how spinifex can be sustainably managed and included in sustainable harvesting practices for Aboriginal communities.

The first part of this thesis introduced the problem and sets the scene for this thesis. Chapter 2 aims to examine Indigenous knowledge and what is known about spinifex in the study area and inland Australia. This chapter examines the physical characteristics of the study site and *Triodia pungens*, and reviews post-burn and IEK literature in terms of sustainable harvesting and resin production. This involves consideration of how *Triodia pungens* and responds to fire, including regeneration traits (seedlings and resprouts), climatic conditions to encourage regeneration, flowering characteristics, resin production, and the use of spinifex in the study region. The literature is used to provide the relevant

data and information and where knowledge is scant, previous ethnographic and scientific research is incorporated into the discussion.

Chapter 3 aims to describe the field experiment methods and analyses undertaken in this study. A one hectare area was sub-divided in to 25 small plots to test for seasonal variations and whether this had an effect on regeneration and growth rates. Permanent recording areas allowed spinifex regeneration to be monitored for the remainder of the study.

Chapter 4 aims to describe the key characteristics of *Triodia pungens* (the term 'spinifex' is used in the following) from field experiments to provide an insight in to previous IEK systems. Pre-burn and pre-harvest recording is presented and this is followed by an explanation of post-burn and harvest spinifex regeneration, resin characteristics in relation to IEK revival, and evidence for flowering events. Statistical analyses are undertaken to determine plant regeneration characteristics, variations between burn and harvest treatments, and variations in each rotating wet and dry season.

Chapter 5 aims to integrate the above information and suggest how spinifex can be sustainably managed and included in commercial applications for sustainable spinifex harvesting in Aboriginal communities. This chapter provides an overview of IEK and makes recommendations for *Triodia pungens* harvesting management strategies in this region. This chapter is concluded with a thesis summary and discussion of future research strategies.

## **Chapter 2**

### **Study Region: Indigenous Ecological Knowledge & Scientific Background**

#### **Introduction**

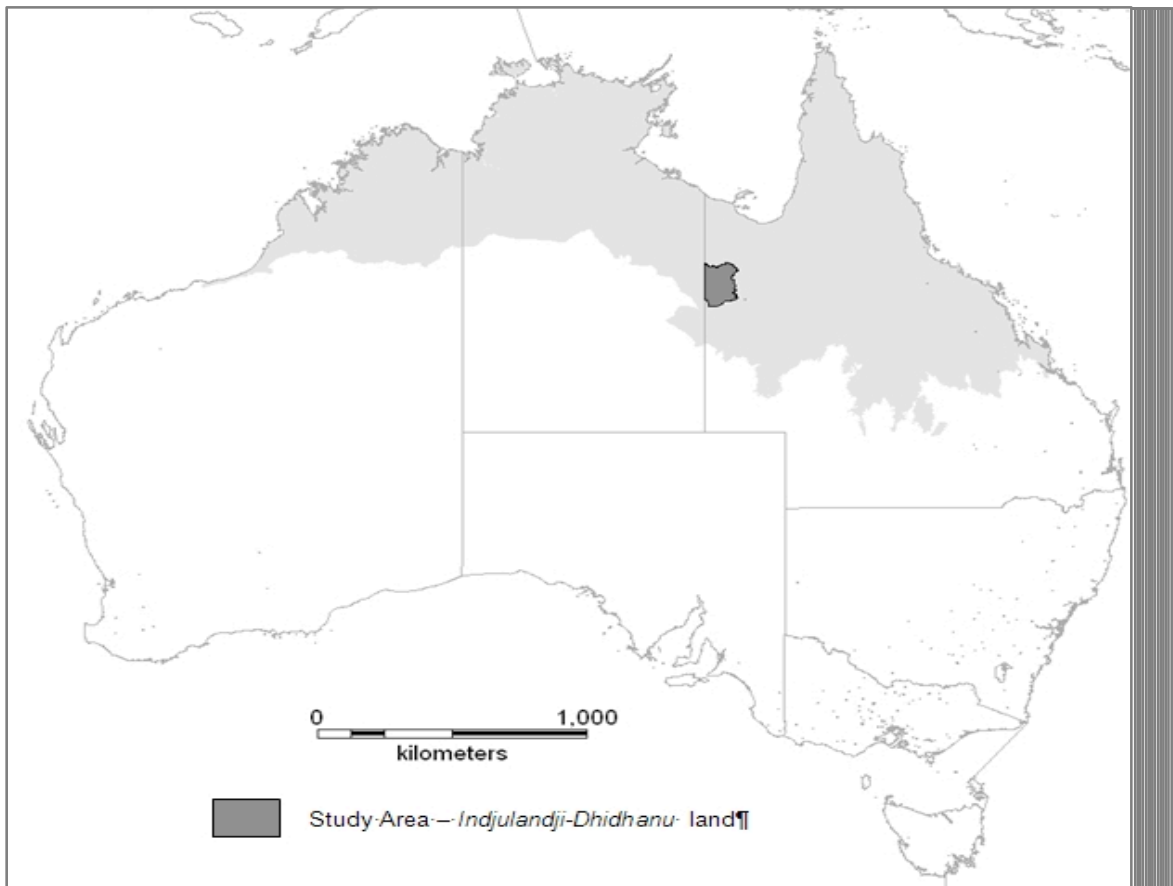
The aims of this chapter are to examine Indigenous knowledge and what is known about spinifex in the study area and inland Australia. The characteristics of the study area, *Triodia pungens*, cultural setting, IEK and spinifex use, and the scientific knowledge are explored at the local and regional level. The literature is used to provide the relevant data and information and where knowledge is scant, previous ethnographic and scientific research is incorporated into the discussion. Section two of the chapter describes the characteristics of *T. pungens*, and the third section examines the scientific and ethnographic literature of *T. pungens* in relation to fire and post-burn regeneration traits.

#### **Physical Setting**

The general study region is defined by the Indjalandji-Dhidhanu Native Title Claim boundary<sup>30</sup>, the Queensland portion of which is located in the lower southwestern portion of the tropical savanna of Queensland on the Northern Territory/Queensland State Border (Fig 4.). The boundaries of the study region are located 72 km northwest of Camooweal on the Northern Territory/Queensland border, and 143 km southeast of Camooweal between latitudes 19°18'45.29"S and 21° 2'52.64"S and longitudes 137°58'30.76"E and 139°11'59.48"E.

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<sup>30</sup> Indjalandji-Dhidhanu Native Title Claim, Federal Court No. QUD243/09. Note, Indjalandji-Dhidhanu land extends in to the Northern Territory but this area is not considered or discussed in this thesis.

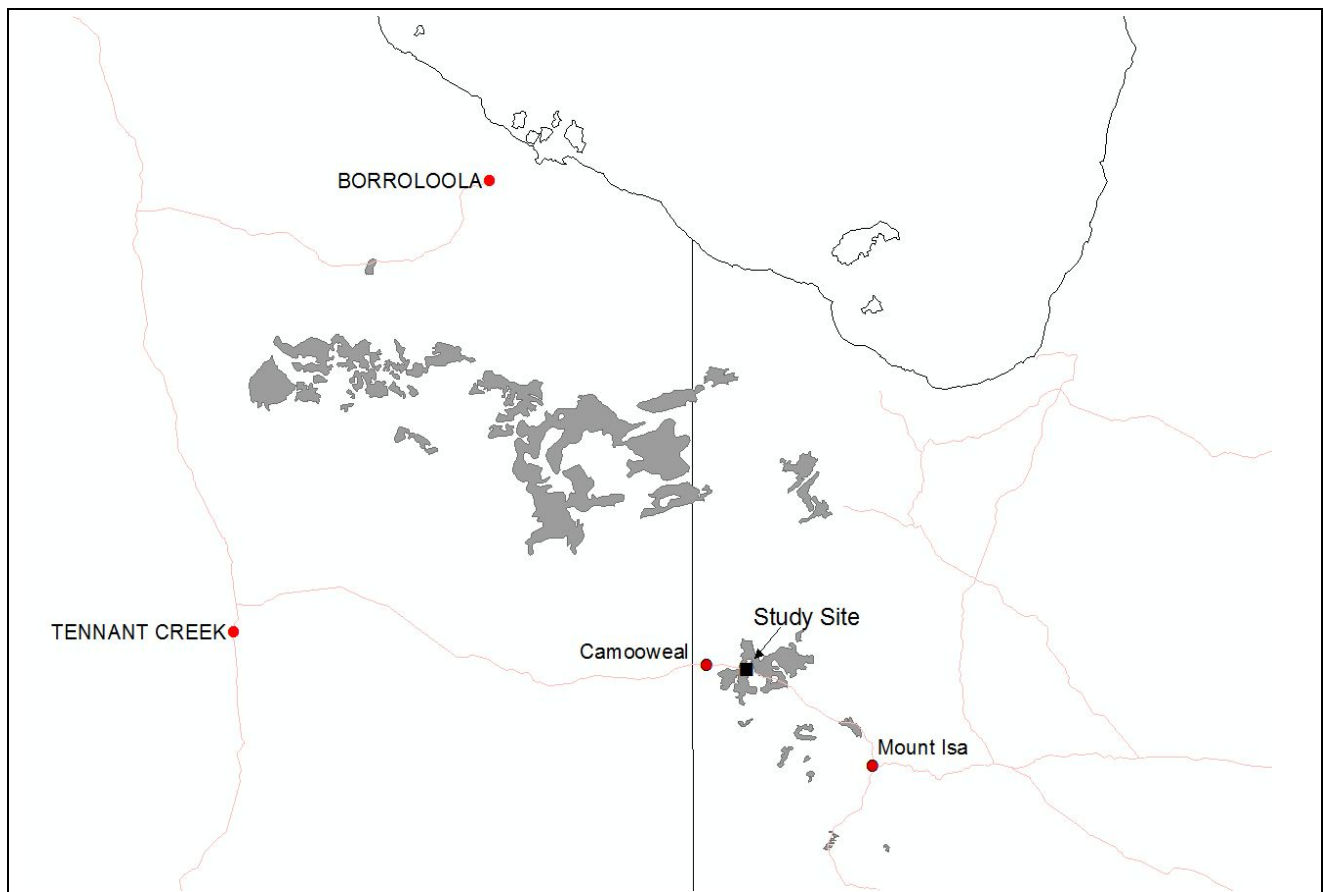


**Figure 4.** The study area is located within the Queensland section of Indjalandji-Dhidhanu lands, within tropical savanna (light grey shading).

The focus of this study is the tropical savanna Land Unit 5, Map Unit D27<sup>31</sup> (Fig. 5). Map Unit D27 is characterised by Cainozoic flat to gently undulating plains comprising uniform extensive sand deposits of usually sandy red earths often overlying lateritic profiles of weathered or un-weathered bedrock<sup>32</sup>.

<sup>31</sup> Fox, I. D., Neldner, V. J., Wilson, G. W., Bannink, P. J., Wilson, B. A., Brocklehurst, P. S., Clark, M. J., Dickinson, K. J. M., Beard, J. S., Hopkins, A. J. M., Beeston, G. R., Harvey, J. M., Thompson, E. J., Ryan, T. S., Thompson, S. L., Butler, D. W., Cartan, H., Addicott, E. P., Bailey, L. P., Cumming, R. J., Johnson, D. C., Schneider, M., Stephens, K. M. and Bean, A. R. (2001). *The Vegetation of the Australian Tropical Savannas, (1:2 000 000 scale map in 3 sheets)*. Queensland Herbarium, Environmental Protection Agency, Brisbane and the Cooperative Research Centre for the Sustainable Development of Tropical Savannas, Darwin. 103.

<sup>32</sup> *ibid.* 103.

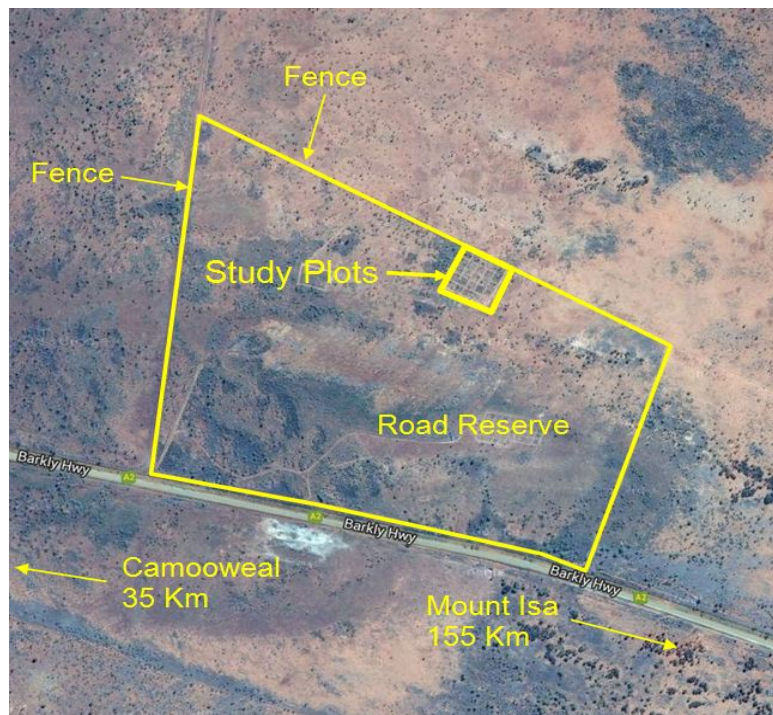


**Figure 5.** Distribution of the D27 Map Unit northern Australia. This area comprises 18,158 sq. km<sup>33</sup>.

This study site is within a fence field, which is now part of the Split Rock pastoral lease and which was made available by the pastoralist for the University of Queensland use (Fig. 6). The field site was dominated by a *T. pungens* grassland with open *Eucalyptus leucophylla* shrubland, and had not been burnt since 2001<sup>34</sup>. The soils are shallow lateritic sediments with areas of outcropping gravel. *T. pungens* occurs in much higher densities in patches of better soil where there is less gravel dispersed on the surface. Minimal grazing had occurred in the field site owing to its location within a former road reserve.

<sup>33</sup> Fox, I. D., Neldner, V. J., Wilson, G. W., Bannink, P. J., Wilson, B. A., Brocklehurst, P. S., Clark, M. J., Dickinson, K. J. M., Beard, J. S., Hopkins, A. J. M., Beeston, G. R., Harvey, J. M., Thompson, E. J., Ryan, T. S., Thompson, S. L., Butler, D. W., Cartan, H., Addicott, E. P., Bailey, L. P., Cumming, R. J., Johnson, D. C., Schneider, M., Stephens, K. M. and Bean, A. R. (2001). *The Vegetation of the Australian Tropical Savannas, (1:2 000 000 scale map in 3 sheets)*. Queensland Herbarium, Environmental Protection Agency, Brisbane and the Cooperative Research Centre for the Sustainable Development of Tropical Savannas, Darwin. 131.

<sup>34</sup> Landgate fire mapping (<http://www.landgate.wa.gov.au/corporate.nsf/web/Imagery>, accessed 08 May 2009).



**Figure 6.** The study plots (100m x 100m) are located beside the Barkly Highway within in an old road reserve. (Google Maps, accessed 24 May 2013).

## Climate

The mean annual rainfall for Camooweal is almost 400 mm per annum, with an average of 33 rain-days each year<sup>35</sup>. The region's climate is characterised by well-defined wet and dry seasons, with almost all the rain falling between December and March. The majority of the wet season rainfall derives from monsoonal rain that falls in successive days, followed by periods of high temperatures, evaporation, transpiration and humidity. Temperatures escalate in October to November prior to the onset of the wet season. Diurnal temperatures are above 35° C during the wet season with average maximum and minimum temperatures of 32.9° C and 17.6° C, respectively<sup>36</sup>. The dry season (April to November) is dominated by clear skies and average daily temperatures of 24° C, with overnight temperatures falling to 12° C (Fig. 7)<sup>37</sup>. Average wind speeds throughout the dry season are 12.1 km/hr increasing to 15 km/hr during September<sup>38</sup>. Approximately 85 mm of rain is needed to maintain plant growth for a period of 28 days and on average the

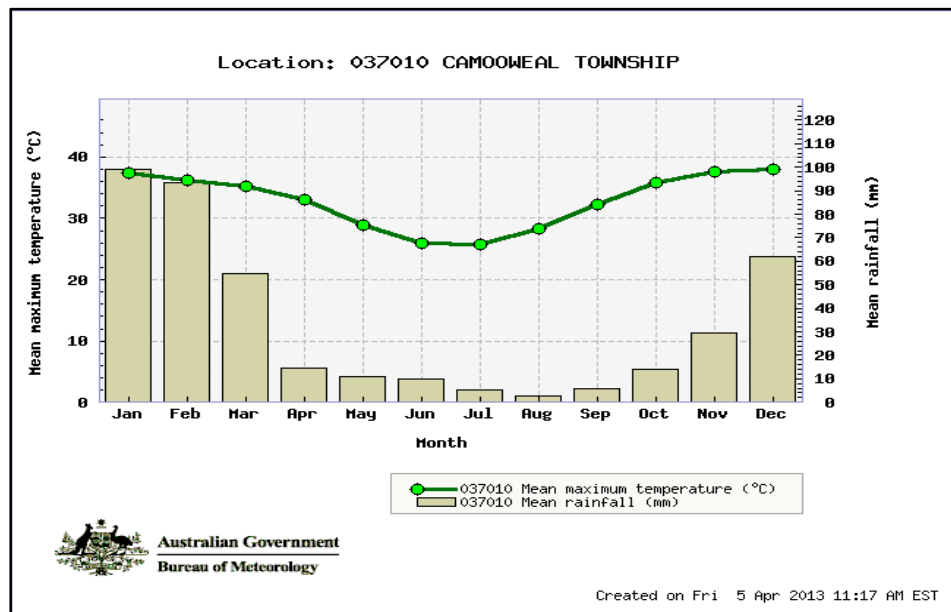
<sup>35</sup> Bureau of Meteorology. <http://www.bom.gov.au/jsp/ncc/cdio/cvg/av>. Accessed, 05 April, 2013.

<sup>36</sup> *ibid.*

<sup>37</sup> *ibid.*

<sup>38</sup> *ibid.*

growing period is seven weeks. The frequency of rainfall and the total number of rain days rather than total rainfall are the most important factor affecting plant growth<sup>39</sup>.



**Figure 7.** Average rainfall and temperature Camooweal Township<sup>40</sup>.

The short growing season occurs between mid-January and mid-February each year making this a defined period and opportunistic time for plant growth<sup>41</sup>. Without rainfall or useable soil moisture, the high temperatures between January and February limit plant growth and places undue stress on plants. Variability in plant growth is a subject of this study, including response to rainfall, and the characteristics of *T. pungens*.

## Flora

The D27 Land Unit extends east across the central area of the study region (Fig. 8). The flora is dominated by low open-shrubland of *Triodia pungens*, *Eucalyptus leucophloia* (snappy gum), *E. pruinosa*, *E. leucophylla*, *Corymbia terminalis*, *C. capricornia*, *Erythrophleum chlorostachys* and *Senna spp.* (Fig. 9). The grassland layer contains scattered *Aristida contorta*, and short-lived annual species such as *Sporobolus spp.* and *Eriachne spp.* *Triodia pungens* and *T. bitextura* (curly spinifex) hummock grasses

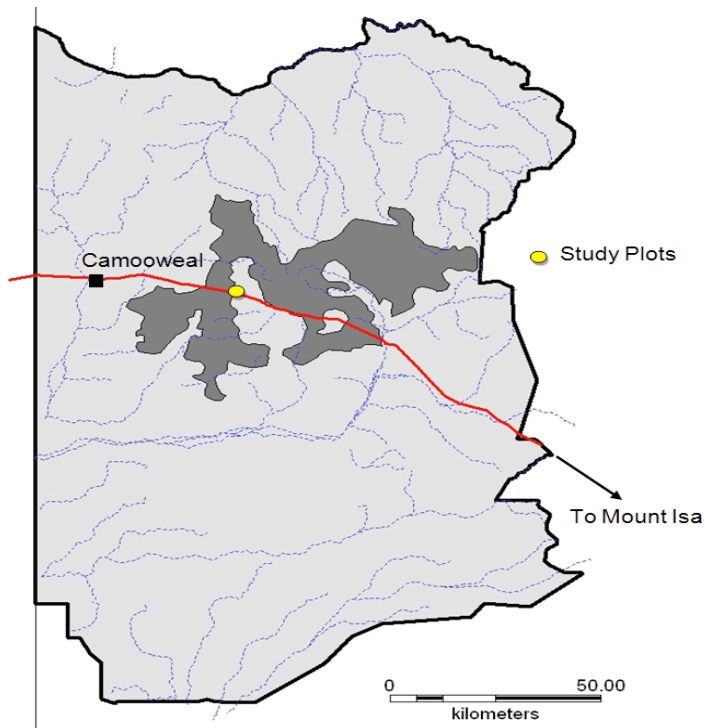
<sup>39</sup> Christian, C., Noakes, R., Slayter, R., Stewart, G., and Traves, D. (1954). Survey of the Barkly Region, Northern Territory and Queensland, 1948-49. *Land Research Series No 3*. Melbourne: Commonwealth Scientific and Industrial Research Organisation. 24.

<sup>40</sup> *ibid.*

<sup>41</sup> *ibid.* 29.



(although the former is the more abundant of the two species) and these species occur mostly on the areas of shallow, gravelly, lateritic soils.



**Figure 8.** D27 Map Unit and location of study plots beside the Barkly Highway within the Indjalandji-Dhidanu Native Title Claim area.



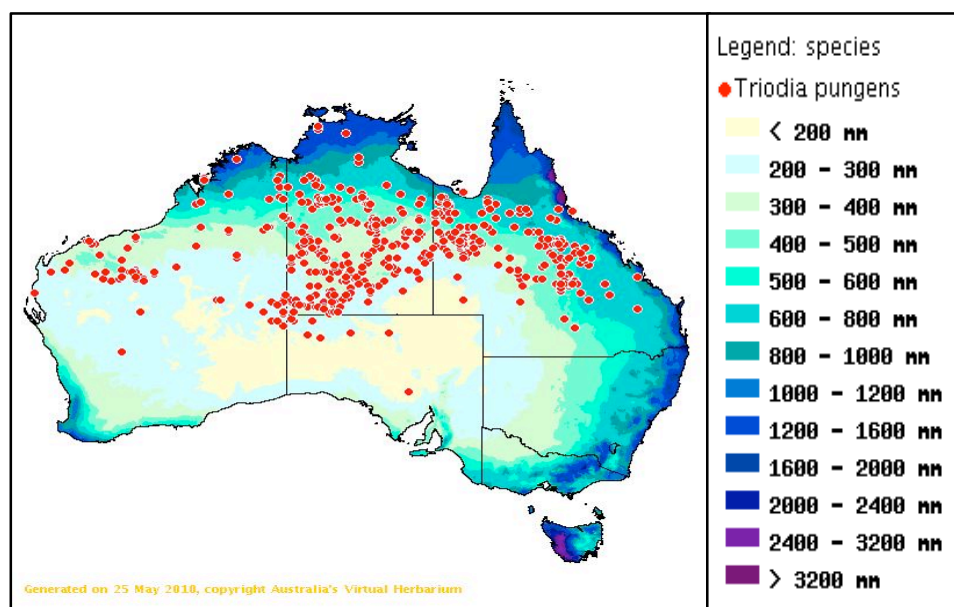
**Figure 9.** D27 Vegetation Unit – *Triodia pungens* grassland and *Eucalyptus leucophylla* woodland.



## General Characteristics of *Triodia pungens*

*Triodia pungens* is found mostly within low soil moisture and low soil nutrients areas and within the 200 – 500 mm rainfall zones of central and northern Australia (Fig. 10)<sup>42</sup>.

*Triodia pungens* is a highly-viscid hummock grass varying in size from 0.5–2 m high and 1–3 m wide (Fig. 10)<sup>43</sup>. *Triodia pungens* has regularly and closely-formed prop-roots (tillers) each with similarly elongated internodes. The distinguishing features of *T. pungens* in particular are its linear dense panicle, a closely-flowered spikelet, a sparsely hairy deeply lobed lemma enclosing the seed, and resinous foliage<sup>44</sup>. The leaf blades stand out at acute angles from the stem. The net effect of this regular pattern of growth in all directions is a hemispherical hummock of closely packed leaves<sup>45</sup> (Fig. 11).



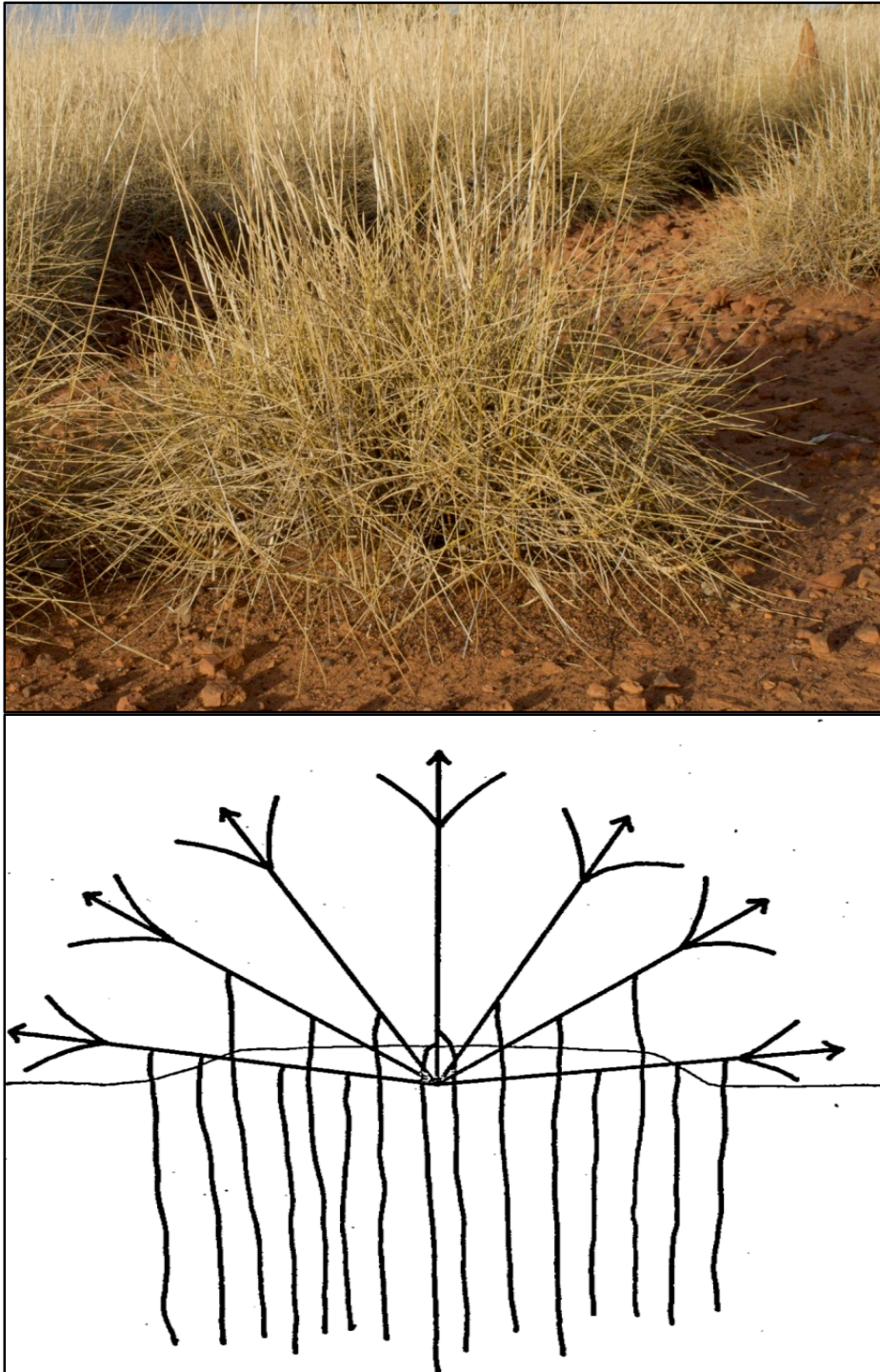
**Figure 10.** Distribution of *Triodia pungens* in comparison to rainfall zones. (Australia's Virtual Herbarium, [http://avh.ala.org.au/occurrences/search?taxa=triodia+pungens#tab\\_mapView](http://avh.ala.org.au/occurrences/search?taxa=triodia+pungens#tab_mapView), accessed, 25 May 2010).

<sup>42</sup> Griffin, G. (1990). Characteristics of three spinifex alliances in Central Australia. *Journal of Vegetation Science*. Vol. 1: 435-444.

<sup>43</sup> Lazarides, M. (1997). A Revision of *Triodia* including *Plectrachne* (Poaceae, Eragrostideae, Triodiinae). *Australian Systematic Botany*. Vol. 10: 464

<sup>44</sup> *ibid.* 465.

<sup>45</sup> Jacobs, S. (1992). Spinifex (*Triodia*, *Plectrachne*, *Symplectrodia* and *Monodia*: Poaceae) in Australia. In, Chapman, G. P. (Ed.), *Desertified Grasslands: Their Biology and Management*. Academic Press, London. 50.



**Figure 11.** *Triodia pungens* hummock showing the general dome-shape, deep root system, and tillers radiating out from the central node<sup>46</sup>.

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<sup>46</sup> Jacobs, S. (1973). *Ecological studies of the genera Triodia R. Br. and Plectachne Henr. in Australia*. Unpublished PhD thesis, Faculty of Science, University of Sydney, Sydney. 16.

*Triodia pungens* plants rarely complete their full flowering cycle of initiation, fertilization and maturation<sup>47</sup>. Flowering occurs over two to three weeks, mostly in the warmer months or after distinct rainfall events<sup>48</sup>. Seed production is restricted to one or two seeds per spikelet in six to eight florets (flowers), with the lowest two florets always without seed<sup>49</sup>. Even within a glasshouse under controlled watering and nutrients conditions, Jacobs found that a maximum of three seeds in eight or more florets were produced over three years<sup>50</sup>. The unreliability and erratic nature of seed production prevents any build-up of seed and thus discourages regular insect attack or predation by birds<sup>51</sup>.

*Triodia pungens* leaves are folded and highly lignified. The leaves are characterised by fewer abaxial<sup>52</sup> stomatal grooves than produce prominent amounts of resin<sup>53</sup> that exudes from the leaves during hot weather and flows down the leaves and stems<sup>54</sup>. Jacobs proposed that resin functions to block the stomates and reduce water loss in the epidermis, and as the temperature falls, the resin solidifies and cracks to allow gas exchange<sup>55</sup>. To date, this hypothesis has not been investigated any further.

Resin also prevents predation and/or attacks by invertebrates<sup>56</sup>, except *Ochetellus flavipes* (spinifex ant)<sup>57</sup>. Colonies of *Ochetellus flavipes* build tunnels from their nests to spinifex hummocks and fashion shelters over spinifex leaves to shroud mealy bugs

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<sup>47</sup> Jacobs, S. (1973). *Ecological studies of the genera Triodia R. Br. and Plectachne Henr. in Australia*. Unpublished PhD thesis, Faculty of Science, University of Sydney, Sydney. 16.

<sup>48</sup> Jacobs, S. (1992). Spinifex (*Triodia*, *Plectrachne*, *Symplectrodia* and *Monodia*: *Poaceae*) in Australia. In, Chapman, G. P. (Ed.), *Desertified Grasslands: Their Biology and Management*. Academic Press, London. 57.

<sup>49</sup> *ibid.* 57.

<sup>50</sup> Jacobs, S. (1973). *Ecological studies of the genera Triodia R. Br. and Plectachne Henr. in Australia*. Unpublished PhD thesis, Faculty of Science, University of Sydney, Sydney. 17.

<sup>51</sup> *ibid.* 17.

<sup>52</sup> Means, facing away from the stem of a plant.

<sup>53</sup> Jacobs, S., (1992). Spinifex (*Triodia*, *Plectrachne*, *Symplectrodia* and *Monodia*: *Poaceae*) in Australia. In, Chapman, G. P. (Ed.), *Desertified Grasslands: Their Biology and Management*. Academic Press, London. 49.

<sup>54</sup> *ibid.* 49.

<sup>55</sup> *ibid.* 55

<sup>56</sup> Jacobs, S. (1992). Spinifex (*Triodia*, *Plectrachne*, *Symplectrodia* and *Monodia*: *Poaceae*) in Australia. In, Chapman, G. P. (Ed.), *Desertified Grasslands: Their Biology and Management*. Academic Press, London. 55.

<sup>57</sup> Morton, S. and Christian, K. (1994). Ecological Observations on the Spinifex Ant, *Ochetellus flavipes* (Kirby) (Hymenoptera: Formicidae), of Australia's Northern Arid Zone. *Journal of Australian Entomology Society*. 33: 309-316.

(coccids), which the ant relies upon for moisture<sup>58</sup>. To build these features, *O. flavipes* bonds grains of sand with spinifex resin to form a continuous tunnel several metres long between spinifex hummocks<sup>59</sup>.

*Ochetellus flavipes* is very sparsely distributed across the *T. pungens* grasslands in fewer than 30 localities across northern Australia<sup>60</sup>. In the study region, *O. flavipes* is largely unknown except with regard to the use of spinifex ant nests by Indjalandji-Dhidhanu people (see below for more information).

## Cultural Setting

At the time of European contact, the Georgina River and its tributaries sustained Indjalandji-Dhidhanu people and formed a thoroughfare for people to trade with adjoining language speakers<sup>61</sup>. In the late 1800s to the early 1900s, Indjalandji-Dhidhanu people were subjected to violence, diseases, and later removal to Aboriginal settlements on the coast, far from their homelands<sup>62</sup>. This caused disruption to their traditional way of life but those families who managed to stay on their lands continued to live a semi-traditional lifestyle, working on cattle stations and maintaining their connections to country. Traditional stone, bone and organic artefacts gave way to steel axes and guns, and the mode of travel changed from foot to horses, and later motor-vehicles, gradually transforming the way people live in and manage their country.

The Indjalandji-Dhidhanu people have maintained their ecological knowledge of spinifex through connections with adjoining Aboriginal groups to the west and southwest of Camooweal. Colin Saltmere, a senior Indjalandji-Dhidhanu man with many years of experience working as a stockman on cattle stations in the region, makes spinifex resin from the nests of the spinifex ant (*Ochetellus flavipes*), and continues to construct shade-

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<sup>58</sup> Morton, S. and Christian, K. (1994). Ecological observations on the spinifex ant, *Ochetellus flavipes* (Kirby) (Hymenoptera: Formicidae), of Australia's northern arid zone. *Journal of Australian Entomology Society*, 33: 314.

<sup>59</sup> Gamage, H., Mondal, S., Wallis, L., Memmott, P., Martin, D., Wright, B., and Schmidt, S. (2012). Indigenous and modern biomaterials derived from *Triodia* ('spinifex') grasslands in Australia. *Australian Journal of Botany*, Vol. 60: 114-127.

<sup>60</sup> Morton, S. and Christian, K. (1994). Ecological observations on the spinifex ant, *Ochetellus flavipes* (Kirby) (Hymenoptera: Formicidae), of Australia's northern arid zone. *Journal of Australian Entomology Society*, Vol. 33: 313.

<sup>61</sup> Graham, L. and Sheldon, S. (2012). *Indjalandji-Dhidhanu. Traditional Ecological Knowledge Project Georgina River, Camooweal North West Queensland. Our vision - Managing River Country*. Dugalundji Aboriginal Corporation, self published report. 12.

<sup>62</sup> *ibid.* 12.

shelters from spinifex hummocks. Shirley Macnamara, a senior Indjalandji-Dhidhanu woman with many years of experience running a cattle station in the region (Colin's sister), regularly visits the Georgina River area and collects local ochres and spinifex fibres for her artworks. These art works feature in national gallery collections<sup>63</sup>.

Saltmere recognised the importance of collaborative research and formed a partnership between the Aboriginal Environments Research Centre (AERC), in the School of Architecture, at the University of Queensland, St Lucia, Brisbane, Queensland and Dugalunji Aboriginal Corporation, which operates in conjunction with the commercial entity of Myuma Pty Ltd<sup>64</sup>. The broader spinifex project (Chapter 1) is important for community development and enables Indigenous people to be actively involved in the carrying out of this research, as well as to benefit from its outcomes.

## Spinifex Management

Since the contact period, spinifex grasslands have been almost entirely managed by pastoralists and non-Indigenous land managers (e.g. park rangers). The local approach to fire management is to remove 'climax' vegetation and encourage perennial species to grow in order to provide better pastures for cattle. The earliest spinifex research considered the use of fire management to improve the grazing values of the genus<sup>65</sup>. In the study region, it is generally known that *T. pungens* grasslands have a much lower cattle-carrying capacity and limited economic value for grazing than do perennial grasslands along the Georgina River frontages<sup>66</sup>. To improve the spinifex-covered lands, pastoralists burn spinifex between November and January each year, prior to the onset of the wet season<sup>67</sup>, to create a veneer of fresh annual and perennial grasses<sup>68</sup>. Thousands of square kilometres of spinifex grasslands are burnt annually by prescribed burning practices.

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<sup>63</sup> Memmott, P. (2010). *Demand responsive services and culturally sustainable enterprise in remote Aboriginal settings: A Case Study of the Myuma Group*. Aboriginal Environments Research Centre Institute for Social Science Research (ISSR) and School of Architecture University of Queensland

<sup>64</sup> Aboriginal Environments Research Centre, Professor Paul Memmott, University of Queensland, Professor, viewed 15 July 2012, <http://www.uq.edu.au/aerc/index.html?page=40399>.

<sup>65</sup> Burbidge, N. (1943). Ecological succession observed during regeneration of *Triodia pungens* R. Br. after burning. *Journal of the Royal Society of Western Australia*. Vol. 27: 155

<sup>66</sup> Craig, A. (1999). Fire management of rangelands in the Kimberley low-rainfall zone: A review. *Rangeland Journal*. Vol. 21(1): 45.

<sup>67</sup> Michael Seymour *pers comm*. Split Rock Station, Camooweal, Queensland, 04 July 2008.

<sup>68</sup> Craig, A. (1999). Fire management of rangelands in the Kimberley low-rainfall zone: A review. *Rangeland Journal*. Vol. 21(1): 45.

Lightning strikes are also responsible for causing a small number of uncontrollable wild fires.

## Spinifex Regeneration

The initial spinifex regeneration studies were conducted by Burbidge in the 1940s, in the sheep grazing areas of Western Australia<sup>69</sup>. Burbidge mapped the locations of plants and described post-burn regeneration of *T. pungens*, which subsequently provided the basis for a small number of studies. Two principal spinifex regeneration mechanisms were documented by Burbidge: seedling and resprouts from a basal crown. These two primary forms of regeneration have been linked to geographical locations: seedlings are correlated with inland areas, and resprouts with coastal regions. However, Rice and Westoby found that each spinifex species, region, and site provides different results<sup>70</sup>.

A third, relatively unknown, means of spinifex regeneration is rapid tiller production, whereby many prop-roots emerge from the stems of plants<sup>71</sup>. This involves the production of many above-ground meristems<sup>72</sup>. A major issue for rapid tiller production is that high intensity fires kill meristematic cells and prevent regeneration<sup>73</sup>. Lenhard and Thomas describe meristematic regeneration as<sup>74</sup>:

...the shoot apical meristem of higher plants is a self-maintaining stem cell system which gives rise to the entire aboveground part of a plant ...The shoot meristem is formed during embryogenesis and subsequently gives rise to internodes, leaves, axillary shoot meristems and flowers.

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<sup>69</sup> Burbidge, N. (1943). Ecological succession observed during regeneration of *Triodia pungens* R. Br. after burning. *Journal of the Royal Society of Western Australia*. Vol. 27: (1940-1941), 149-156.

<sup>70</sup> Rice, B. and Westoby, M. (1999). Regeneration after fire in *Triodia* R. Br. *Australian Journal of Ecology*. Vol. 24: 563-572.

<sup>71</sup> Jacobs, S. (1992). Spinifex (*Triodia*, *Plectrachne*, *Symplectrodia* and *Monodia*: Poaceae) in Australia. In, Chapman, G. P. (Ed.), *Desertified Grasslands: Their Biology and Management*. Academic Press, London. 57.

<sup>72</sup> *ibid.* 58.

<sup>73</sup> Jacobs, S. (1992). Spinifex (*Triodia*, *Plectrachne*, *Symplectrodia* and *Monodia*: Poaceae) in Australia. In, Chapman, G. P. (Ed.), *Desertified Grasslands: Their Biology and Management*. Academic Press, London. 58.

<sup>74</sup> Lenhard, M. and Thomas, L. (1999). Shoot meristem formation and maintenance. *Current Opinion in Plant Biology*, Vol. 2: 44.

Fire reduces the dormancy of spinifex seeds, with seedlings emerging around the edges of the pre-burn hummocks after 40 mm of rain<sup>75</sup>. Jacobs also found that *T. pungens* seeds subjected to temperatures between 30° C and 35° C with adequate waterings successfully germinated in the laboratory<sup>76</sup>. Bogusiak *et al.*<sup>77</sup> found that rainfall of 30–40 mm in summer and autumn, and to a lesser degree in winter, is ideal for spinifex regeneration. Unlike many other plants, adding ash and nutrients to the soil had no influence on spinifex soil-seed germination or enhancement of its growth or production of green tissue<sup>78</sup>. It is suggested that the highly-developed ability of spinifex to store nutrients constricted the plant's ability to accelerate growth in the presence of additional nutrients<sup>79</sup>.

Once spinifex seedlings and juveniles have been established, the numbers of plants decreases significantly with increasing time since fire, while the percentage of adults and dead plants increase<sup>80</sup>. Young perennial plants tend to clump, though with increasing age plants became more randomly spaced due to the elimination of individuals that are in direct competition<sup>81</sup>. All of the available evidence suggests that a burned patch of spinifex will recover within three years to seven years<sup>82</sup>.

To maintain reliable seed banks to aid post-burn regeneration, spinifex flowering and seed dispersal is required, although spinifex is well known for its very poor seed production<sup>83</sup>. Seeds accumulate in the soil during flowering events and lay dormant until the ground is swept by fire. Seeds that fall within the confines of the parent hummock are

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<sup>75</sup> Jacobs, S. (1992). Spinifex (*Triodia*, *Plectrachne*, *Symplectrodia* and *Monodia*: Poaceae) in Australia. In, Chapman, G. P. (Ed.), *Desertified Grasslands: Their Biology and Management*. Academic Press, London. 57.

<sup>76</sup> *ibid.* 51.

<sup>77</sup> Bogusiak, A., Rice, B., and Westoby, M. (1990). Seedling emergence of hummock grasses in relation to the effects of fire. *Australian Rangelands Journal*. Vol. 12(1): 26.

<sup>78</sup> Rice, B., Westoby, M., Griffin, G. and Friedel, M. (1994). Effects of supplementary soil nutrients on hummock grasses. *Australian Journal of Botany*. Vol. 42: 696.

<sup>79</sup> *Ibid.* 696.

<sup>80</sup> Felderhof, L. (2007). *The fire patchiness paradigm: a case study in northwest Queensland*. PhD Thesis, James Cook University. 82.

<sup>81</sup> Felderhof, L. (2007). *The fire patchiness paradigm: a case study in northwest Queensland*. PhD Thesis, James Cook University. 82.

<sup>82</sup> Griffin, G. (1990) Characteristics of three spinifex alliances in Central Australia. *Journal of Vegetation Science*. Vol. 1: 435-44.

<sup>83</sup> Latz, P. (2004). *Bushfires and Bushtucker. Aboriginal Plant Use in Central Australia*. Institute for Aboriginal Development Press Alice Springs, Northern Territory. 9



less likely to germinate because they are in direct competition with the adult plant<sup>84</sup>. However, Latz suggests that *T. pungens* produces very little seed, if any at all, and the glumes are largely empty after flowering<sup>85</sup>. *Triodia pungens* rarely completes its sexual reproductive cycle unless there are above average rainfall and prolonged periods of soil moisture<sup>86</sup>.

Adequate summer rainfall is required for flowering to occur, and inflorescence stems will remain on plants for up to two years<sup>87</sup>. Craig reported that 29 inflorescence stems per square metre after above average rainfall in January<sup>88</sup>.

## Environmental Impacts

Griffin noted that fires can change the structure of the environment and cause changes in local species compositions<sup>89</sup>, due to the fact that it eradicates fire-intolerant species such as *Acacia aneura*<sup>90, 91</sup>. Fires can denude an area or remove the majority of its ground cover and cause topsoil loss on upper hill-slopes and plains if follow-up rain or the timing of fires is not appropriately managed<sup>92, 93</sup>. It is also suggested that if all seeds fail to

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<sup>84</sup> Jacobs, S. (1992). Spinifex (*Triodia*, *Plectrachne*, *Symplectrodia* and *Monodia*: Poaceae) in Australia. In, Chapman, G. P. (Ed.), *Desertified Grasslands: Their Biology and Management*. Academic Press, London. 57.

<sup>85</sup> Latz, P. (2004). *Bushfires and Bushtucker. Aboriginal Plant Use in Central Australia*. Institute for Aboriginal Development Press Alice Springs, Northern Territory. 9.

<sup>86</sup> Jacobs, S. (1992). Spinifex (*Triodia*, *Plectrachne*, *Symplectrodia* and *Monodia*: Poaceae) in Australia. In, Chapman, G. P. (Ed.), *Desertified Grasslands: Their Biology and Management*. Academic Press, London. 57.

<sup>87</sup> *ibid.* 56.

<sup>88</sup> Craig, A. (1993). *The post-fire regeneration of plant communities dominated by Triodia pungens in the vicinity of Newman, WA*. Unpublished Master of Applied Science thesis, Curtin University of Technology. 48.

<sup>89</sup> Griffin, G. (1984). Hummock grasslands. In, Harrington, G. N., Wilson, A. D. and Young, M. D. (Eds.), *Management of Australia's Rangelands*, 271-284. Australia: Commonwealth Scientific and Industrial Research Organisation.

<sup>90</sup> Latz, P. (2007). *The Flaming Desert: Arid Australia - A Fire Shaped Landscape*. Institute for Aboriginal Development Press, Alice Springs, Northern Territory. 89.

<sup>91</sup> Cheney, N., and Sullivan, A. (2008). *Grassfires: Fuel, Weather and Fire Behaviour*. 2nd Edition. Melbourne: Commonwealth Scientific and Industrial Research Organisation Publishing.

<sup>92</sup> Dyer, R., Russell-Smith, J., Grice, T., McGuffog, T., Cooke, P., and Yibarbuk, D. (2001). Using fire to manage savanna. In, R. Dyer, P. Jacklyn, I. Partridge, J. Russell-Smith, and D. Williams, (Eds): *Savanna Burning: Understanding and Using Fire in Northern Australia*. Tropical Savanna Cooperative Research Centres, Darwin, Northern Territory. 50-80.

<sup>93</sup> Williams, D. and Cook, G. (2001). Savanna fire regimes. In, R. Dyer, P. Jacklyn, I. Partridge, J. Russell-Smith, and D. Williams, (Eds): *Savanna Burning Understanding and Using Fire in Northern Australia*, Tropical Savanna CRC, Darwin, Northern Territory. 26.



germinate in a single season after a fire event, then a subsequent drought may hinder spinifex seed survival. There is also evidence for significant regeneration trends following a fire including the type of fire (hot or cold fires)<sup>94</sup>. Rice and Westoby have suggested that fire-killed spinifex is more likely to lead to local extinctions than resprouters<sup>95</sup>.

## Indigenous Ecological Knowledge and Resin Cycles

The spinifex resin extraction process developed by Aboriginal people has been partially documented through ethnographic research and field observations. Baldwin Spencer recorded Aboriginal people extracting resin from spinifex during his travels to Central Australia in 1894 with *The Horn Expedition*<sup>96</sup>, as did Walter Roth (southeast of the study region)<sup>97</sup> and Charles Chewings<sup>98</sup>.

*Triodia pungens* is the most common of the 26 soft resinous spinifex species used by Aboriginal people to make spinifex resin cakes. Pitman and Wallis identified many uses for spinifex resin and fibres<sup>99</sup>, and Powell *et al.* examined plant resin use and concluded that there geographical limitations with spinifex resin use and concluded that spinifex uses was restricted to the far central northwestern Queensland<sup>100</sup>. Spinifex resin has thermoplastic properties and softens when heated at low temperature (50° C to 60° C). It may also be reused again simply by heating it and reworking it. Resin was used for patching holes and cracks in wooden bowls that were used for carrying water, and resin was shaped to form a hand grip on the end of a woomera and stone knife (Fig. 12), and to make toys and ceremonial objects, amongst other uses<sup>101</sup>. A small number of plants are used to make a sizeable cake of resin that can be carried and used and reused for a long period of time.

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<sup>94</sup> Rice, B. and Westoby, M. (1999). Regeneration after fire in *Triodia* R. Br. *Australian Journal of Ecology*. Vol. 24: 563.

<sup>95</sup> *ibid.* 571.

<sup>96</sup> Spencer, B. Sir. (1928). *Wanderings in Wild Australia*. MacMillan, London. 572.

<sup>97</sup> Roth, W. (1897). *The Queensland Aborigines, Volume 1*. (Ed.) MacIntyre, K. F. Aboriginal Studies No. 2. Hersperian Press, Western Australia. 101-102.

<sup>98</sup> Chewings, C. (1937). *Back in the Stone Age: The Natives of Central Australia*. Angus and Robertson, Sydney. 42.

<sup>99</sup> Pitman, H. and Wallis, L. (2012). The point of spinifex: Aboriginal uses of spinifex grasses in Australia. *Ethnobotany Research & Applications*. Vol. 10: 126.

<sup>100</sup> Powell, O., Fensham, R., and Memmott, P. (2013). Indigenous use of spinifex resin for hafting in north-eastern Queensland. *Economic Botany*. Vol. 67(3): 223.

<sup>101</sup> Pitman, H. and Wallis, L. (2012). The point of spinifex: Aboriginal uses of spinifex grasses in Australia. *Ethnobotany Research and Applications*. Vol. 10: 125.



**Figure 12.** Coolamon patched with resin (left) and woomera with spinifex resin handle (right) (Utility Artefact Collection, Strehlow Research Centre, Alice Springs, Northern Territory, accessed 10 September 2013).

The previous approaches to recording IEK about spinifex have been to document resin use. Binford for example, recorded Alyawarre language speakers (men) selecting, harvesting, and processing spinifex to produce a sizeable cake of resin<sup>102</sup>. However, Binford did not record the details as to how and why they selected a suitable group of plants for processing. Whilst Binford did not record this, it is suggested that this is an important step in the spinifex resin processing process and developing a good understanding of resinous spinifex plants.

## Summary

The aim of this chapter has been to set the scene for this study by providing brief overviews of the physical environment, cultural setting, previous work on IEK and scientific knowledge of *Triodia pungens* at local and regional levels. The current view is that spinifex regenerates by seedlings and resprouts, and that it is highly responsive to fire after summer and autumn rainfall, and to lesser degree that which occurs in winter<sup>103</sup>. Most of the scientific studies on spinifex regeneration have targeted post-burn monitoring of spinifex regrowth characteristics, monitoring the number of seedlings that emerge after each distinctive rainfall event following a fire.

<sup>102</sup> Binford, L. (1984). An Alyawara day: flour, spinifex gum, and shifting perspectives. *Journal of Anthropological Research*. Vol. 40(1): 157-182.

<sup>103</sup> Rice, B. and Westoby, M. (1999). Regeneration after fire in *Triodia* R. Br. *Australian Journal of Ecology*. Vol. 24: 570.

Whereas spinifex regeneration is guaranteed to occur after fire, the manner in which it regenerates has not been pinpointed to any particular species and region. Mechanisms of spinifex regeneration will vary according to geographical and site variations including soil type, climatic variation, topography, and local site attributes<sup>104</sup>. Past results suggest *T. pungens* plants in northern Australia will resprout from plant crowns burnt by fire, though adding ash, phosphorous and nitrogen has little to no effect on spinifex regeneration. There is no research available to indicate whether the absence of heat and/or smoke will affect the ability of *T. pungens* to regenerate in a post-harvesting regime.

In spite of the spinifex regeneration research conducted to date, the uneven geographic spread of research and biases towards particular species has resulted in major gaps remaining in our understandings of spinifex grasslands. In addition, IEK emerges as an important framework for conducting this research. The interconnectedness should be the subject of research in its own right and this should be used to develop our understanding of spinifex.

Jacobs postulated that *Triodia pungens* produces resin which on hot days solidifies and cracks, allowing gas exchange—he challenged others to test his hypothesis<sup>105</sup>. Knowing when resin is suitable for harvesting is yet to be developed. Ethnographers have overlooked Aboriginal understandings of the field characteristics of spinifex and why they chose specific plants for resin extraction<sup>106, 107</sup>. Our knowledge of when it should be extracted and under what conditions, including time of year and plant size and age, remain unclear. The investigation of resin characteristics in the study region therefore has the potential to respond to these research questions and contribute to the broader project outcomes.

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<sup>104</sup> Rice, B. and Westoby, M. (1999). Regeneration after fire in *Triodia* R. Br. *Australian Journal of Ecology*. Vol. 24: 570.

<sup>105</sup> Jacobs, S. (1992). Spinifex (*Triodia*, *Plectrachne*, *Symplectrodia* and *Monodia*: Poaceae) in Australia. In, Chapman, G. P. (Ed.), *Desertified Grasslands: Their Biology and Management*. Academic Press, London. 55.

<sup>106</sup> For example, Binford, L. R. (1984). An Alyawara day: flour, spinifex gum, and shifting perspectives. *Journal of Anthropological Research*. Vol. 40(1): 157-182.

<sup>107</sup> For example, Latz, P., (2004). *Bushfires and Bushtucker. Aboriginal Plant Use in Central Australia*. Institute for Aboriginal Development Press Alice Springs, Northern Territory. 290-293.

A further issue is that unknown amounts of resin are lost by senescence. As older plant increase in size, the centre of the plant dies in an outward direction, and the leaves and stems are no longer useful for resin production. Plant age or time since fire or harvesting effects is therefore an important consideration for resin production. For example, old hummocks with dead leaves and stems fail to produce any resin. As a result, these plants are effectively unusable for the extraction of resin. It is suggested that Aboriginal people may have targeted these older, less useful plants in their fire management strategy. These old plants with dried leaves (which turn grey in colour) burn with considerable intensity and will carry fires.

A further problem is the lack of documented IEK of spinifex in the study region. Aboriginal knowledge of spinifex in Australia is shrouded by the impacts of colonisation and assimilation policies, which have affected Aboriginal knowledge systems and cultural epistemologies. Indigenous plant knowledge has been compromised by an absence from traditional lands and the removal of knowledge transfer to the younger generations of Aboriginal people, but is considered critical approach to understanding spinifex-harvesting and its ecological characteristics.

## **Chapter 3**

### **Methods: Examining Sustainable Harvesting & Indigenous Ecological Knowledge**

#### **Introduction**

This chapter describes the field experiment methods utilised and analyses carried out in this study. Data was collected over three wet seasons (March 2009 to May 2011) to document regeneration traits, growth rates, resin cycles and flowering events. This involved selection of a suitable study site, development of a research design, including a data collection strategy, and determining suitable methods for data analysis.

#### **Fire and Harvesting Program**

This research used small fixed recording areas to monitor the regeneration of individual plants on the 25 plots biannually (dry and wet season). This study focused on plant demographics, e.g. emergence and mortality, daily growth rates, and resin and flowering cycles, for documenting post-burn and post-harvesting regeneration and addressing questions about IEK revival. It was not possible to record all the plants on the plots so a sub-sampling strategy was used to assess a proportion of the plants, rather than using single recording areas verses a series of transects or a multiple quadrat sampling techniques. A key problem of this methodology concerns the resultant small sample size, which was considered unavoidable due to limited time and resources.

The plot area was subdivided into ten dry season, ten wet season, and five control plots (Fig. 13), to compare the effects of fire and harvesting on spinifex regeneration and time of year at which it occurs. Individual plots were distributed randomly across the experimental by passing the four experimental groups and controls through a random number generator in Microsoft Excel. By positioning experimental or control plots randomly, this avoided any ecological and environmental biases that would exist if they were placed side by side.

1. Control	2. DSH	3. WSH	4. DSB	5. DSB
6. WSH	7. WSH	8. WSB	9. DSH	10. Control
11. WSB	12. WSH	13. DSB	14. WSB	15. DSB
16. DSB	17. DSH	18. WSB	19. Control	20. DSH
21. WSH	22. DSH	23. Control	24. WSB	25. Control

**Figure 13.** The distribution of experimental and control plots. Each plot measured 17 m by 17 m. A 3.75 m firebreak was placed between each plot and around the outside of the experimental area to avoid issues with fire escaping during the experiments and encroachment of wildfires in to the plots during the three-year study.

**Key:**

DSH = Dry Season Harvest

DSB = Dry Season Burn

WSH = Wet Season Harvest

WSB = Wet Season Burn

Control = no harvesting or burning

Prior to undertaking the burn and harvest experiments, spinifex plant characteristics were recorded to provide pre-burn and pre-harvest baseline data. This occurred in the 2008 dry season and 2009 wet season using the same plant recording methods that were used in the subsequent monitoring program (see details below) i.e. crown size and height, resin levels and flowering events. These recordings aimed to provide a commencement sample record of all the plots including the control, which were monitored throughout this study. The control plots provide a continuous record of hummocks if left unburned and not harvested.

*Dry and Wet Season Fires.* The dry season plots were burned once only, in the 2008 dry season. The wet season plots were burned on a single occasion in 2009 wet season to test whether seasonal fires affected spinifex regeneration. As mentioned in Chapter 2, landholders burn in the wet season as this arguably provides a better opportunity for other grass species to regenerate and produce pasture for cattle grazing. It is known that resin flows from the leaves during the wet season, while in the cooler days of the dry season, the resin solidifies and cracks<sup>108</sup>. Latz suggested that spinifex will burn with greater intensity during the dry season<sup>109</sup>. The cooler temperatures in the dry season, however, are more suitable for the harvesting of spinifex and it is at this time that the dried resin may be more easily dislodged from the dried leaves and stems.

Fire permits were obtained from the Queensland Department of Natural Resources and Mines to carry out the dry and wet season burns. A mobile fire unit and fire extinguishers were put on standby in case fire escaped and spread to other plots or to adjoining grasslands. Aboriginal trainees and mentors from the Myuma Training Centre in Camooweal conducted the burns for all plots (Fig. 14).

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<sup>108</sup> Jacobs, S. (1992). Spinifex (*Triodia*, *Plectrachne*, *Symplectrodia* and *Monodia*: *Poaceae*) in Australia. In, Chapman, G. P. (Ed.), *Desertified Grasslands: Their Biology and Management*. Academic Press, London. 55.

<sup>109</sup> Latz, P. (2007). *The Flaming Desert: Arid Australia - A Fire Shaped Landscape*. Institute for Aboriginal Development Press, Alice Springs, Northern Territory.



**Figure 14.** Aboriginal trainees burning spinifex at the study site.

The initial burning technique used allowed the fire to spread unassisted across the study area. However, weather conditions, hummock sizes, and spaces between the hummocks often prevented fires from spreading naturally across the plots. Whilst patchiness is a key to the survival of spinifex in the natural ecosystem, for the purposes of this study it was important that all hummocks were removed during the burn event (as harvesting removes all hummocks in a similar manner to commercial crop harvesting). Therefore, when necessary, individual hummocks were lit to remove all hummocks from within the plant monitoring areas. However, despite these efforts, owing to human error some plants survived the fire events. These instances are noted in the data recordings and analysis.

Fires affected hummocks in different ways. To record post-burn plant status, hummocks were divided into three categories:

1. Plants that were totally destroyed by the fire;
2. Plants that were partially affected by the fire and;
3. Plants that were not affected by the fire.



**Dry and Wet Season Harvesting.** Mechanical harvesting methods aimed to remove hummocks at ground level to avoid excessive ground disturbance and potential irreparable damage to root systems and soil seed banks. Dry Season treatment plots were harvested using a Caterpillar bobcat with a 1.5 m-wide bucket set slightly above ground level to cut hummocks off above the main root stems (Fig. 15). Several passes across each plot were made until the bobcat bucket was filled with hummocks, which were then deposited off-site. This process was repeated until all hummocks in each plot were removed.



**Figure 15.** Mechanical harvesting of *Triodia pungens*. Hummocks were severed above ground level and removed from the plots. Joel Saltmere, *Indjalandji-Dhidanu* man, carrying out mechanical harvesting, during the dry season (July 2008).

The 880 mm of rain that fell between late December 2008 and March 2009 raised concerns about possible damage being caused to the soil surface and soil seed banks by the bobcat wheel tracks and so, for the March 2009 wet season treatment, hand harvesting was used instead. Aboriginal trainees manually harvested individual hummocks using shovels to carefully remove the spinifex plants, which were then deposited beyond the experimental plots.



**Figure 16.** Aboriginal trainees hand-harvesting spinifex during the March 2009 wet season.

## Monitoring Program

As noted in Chapter 2, spinifex has two main regeneration forms: 1) obligate-seeders, that tend to be produced in the instance of fire-killed spinifex and, 2) vegetative resprouters, where the plant buds survive fire and sprout the basal crowns<sup>110</sup>. These forms of regeneration will influence how spinifex regenerates within the study area. Prior to the commencement of the experiments, hummocks were cut to determine the growth form e.g. stoloniferous or basal leaf crowns. By determining the growth form, it would provide a basis for the type of expected spinifex regeneration, e.g. basal leaf sprouter or obligate-seeder.

Spinifex hummock sizes, and resin and inflorescence scores describe each hummock within the monitoring areas and provide a baseline dataset for comparing the outcomes of these experiments. Prior to the initial treatments, it was important to examine

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<sup>110</sup> Rice, B. and Westoby, M. (1999). Regeneration after fire in *Triodia* R. Br. *Australian Journal of Ecology*. Vol. 24: 564.

plant demographics (sizes and numbers of plants) and growth forms of *T. pungens* within the monitoring area of each plot.

A permanent circular "monitoring area" four metres in diameter (12.57 m<sup>2</sup> area or four percent of the total plot area) was randomly located on each of the 25 plots within which to record individual plant data. The location of each sampling area was selected using a point generator and a permanent recording peg driven in to the ground to mark its centre.

Dry season experiments were completed in July 2008, and wet season experiments were finished in March 2009. Monitoring commenced in March 2009 and continued until May 2011, and the wet season recordings began in November 2009 and concluded in May 2011 (Table 1). Whilst additional field recording in the middle of dry and wet season could have provided a further data point to examine plant regeneration and resin cycles, the number of recordings were limited by project budgets and field resources. Accordingly, it was decided to monitor changes in plant demographics by targeting the end of the dry season (November), which is the dormancy phase for spinifex, and the end of the wet season (May), which is the end of the growing period.

**Table 1** Individual monitoring events and time since treatment.

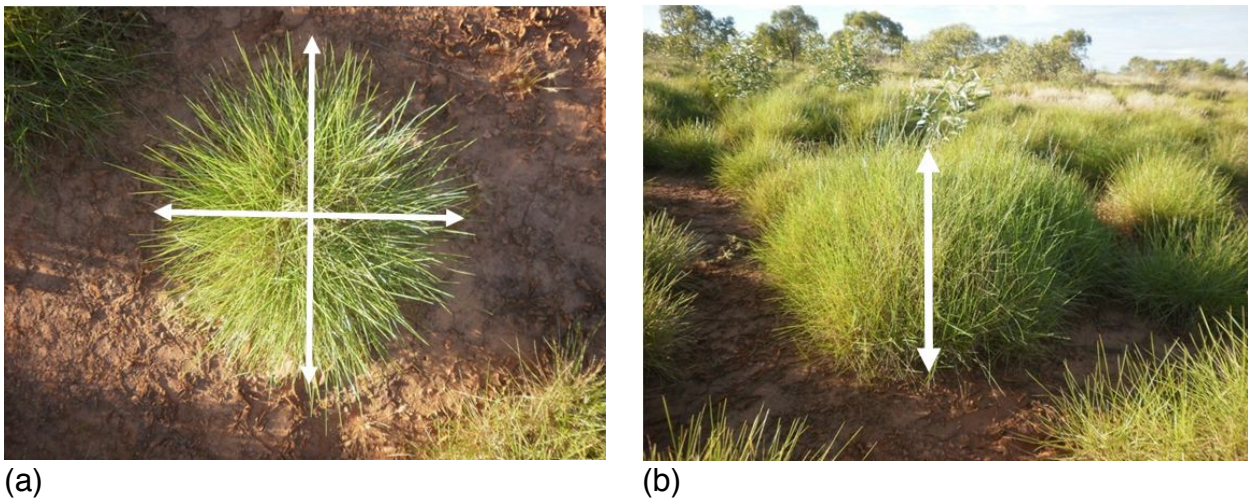
Date	Time (Dry Season)	Time (Wet Season)
July 2008	Burn and harvest	NA
March 2009	8 months	Burn and Harvest
June 2009	11 months	3 months
November 2009	16 months	8 months
May 2010	21 months	14 months
November 2010	26 months	20 months
May 2011	33 months	26 months

*Plant regeneration.* Information about plant demographics (e.g. numbers and sizes) and location of plants were collected and entered into a spreadsheet for analysis. Changes in plant demographics were then assessed over the length of the study to compare the results, particularly growth rates and attrition. Plant location data was recorded from the respective recording peg to the centre of the plant by measuring the distance (centimetres) and direction (using a compass). Attributes of all individual plants



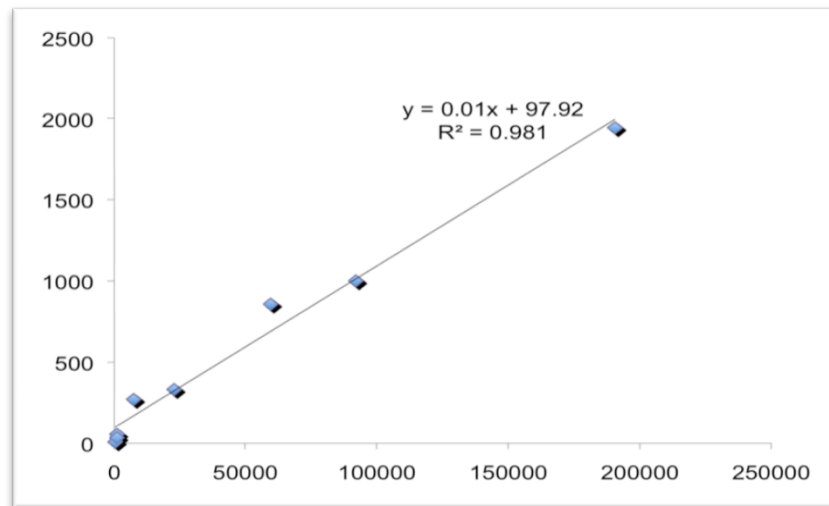
within the monitoring area of each treatment plot were recorded biannually with the author carrying out all data acquisition to ensure consistency in data recording.

*Plant measurements.* The plant-recording methods considered the ‘dome’ or half an ellipsoid shape of spinifex. To collect the size and volume of each plant, the “north-south” and “east-west” crown diameters were recorded to the nearest centimetre (Fig. 17a). For height, a small tape measure was fed through the approximate centre of each hummock to measure the distance from the leaf extremities to ground level (to the nearest cm) (Fig. 17b). To approximate the size of each hummock, half the volume of an ellipsoid was used.



**Figure 17.** Explanation of the measurements recorded for individual plants: (a) plan view showing the how crown size was measured; and (b) side view showing height measurement as recorded at the approximately centre of each plant.

Biomass was used as a measurement of daily regrowth rates within the burn and harvest plots. Biomass was calculated from plant volume and plant weights (Fig. 18) and used in the linear growth model, which is presented in the following section.



**Figure 18.** Linear correlation between plant volume and dry weights.

**Resin cycles.** Resin stickiness was used to describe resin cycles. By examining the leaves and stems of all plants, plants were assigned a 'resin score' determined through comparison with the resin characteristics presented in Table 2. Observations provided an indication of hummock dormancy and active growth stages.

**Table 2.** List of resin score indicators developed for the purposes of this study.

Resin Score	Indicator
1	Leaves and stems not sticky
2	Leaves and stems mildly sticky
3	Resin forming droplets
4	Resin flowing down stems

In addition to recording resin cycles, resin extraction experiments were completed in July 2008 and November 2009 to test whether resin could be extracted from plants using the method described by Binford<sup>111</sup>. Approximately 10 plants were cut off at ground level and placed in a pile for threshing. After threshing the dislodged material was collected and winnowed, and then heated to make a small cake of resin. The aim of conducting these tests was to complement the resin stickiness data.

<sup>111</sup> Binford, L. (1984). An Alyawara Day: Flour, Spinifex Gum, and Shifting Perspectives. *Journal of Anthropological Research*. Vol. 40(1): 157-182.

**Flowering and inflorescences.** The number of inflorescence stems was counted for every plant within the monitoring areas of each of the 25 plots and assigned a score based on the count ranges presented in Table 3. These results were used to compare responses to rainfall events, plant ecology, and plant maturity. This is discussed in more detail in Chapter 4.

**Table 3.** Score and number of inflorescence stems in each range.

<b>Inflorescence Score</b>	<b>Range</b>
1	1-3
2	4-10
3	11-30
4	31-100
5	101-300
6	300-1000

**Regrowth mechanisms.** The regrowth mechanisms for spinifex plants with 9–15 leaves were randomly examined beyond the monitoring areas of the plots from within the fire breaks. A random number of small plants (n=28) was examined for the presence of fine root hairs, which were more likely to derive from seed germination, and coarse root systems, which align with meristematic regeneration. These plants were excavated using a small trowel to expose the root systems and underlying rootstocks. The term ‘recruit’ was used to make distinctions between instances of seedlings and below-ground meristematic regeneration.

In addition, the little known rapid tiller production regeneration type, which is discussed in Chapter 2, was observed within the monitoring areas. It was clear that the presence of new tillers and stems on plants would represent this form of regeneration.

**Climate data.** Monthly rainfall and temperature data were obtained from the Bureau of Meteorology website ([www.bom.gov.au](http://www.bom.gov.au)) for the Camooweal Meteorological Station. This station is located 35 km west of the study site. Rainfall data was obtained for the period July 2008 to May 2011. These data were used to identify monthly and daily rainfall totals for each month. Consecutive rain days and total rainfall above 40 mm were important for providing adequate soil moisture to stimulate plant growth and regeneration.

## Data Analysis

All data were entered in to a Microsoft Excel spreadsheet for analysis. The following quantitative and qualitative data were summarised for each plot:

### Quantitative:

- Number of plants in each monitoring area within of each plot at the start of the study;
- Percent survivors and attrition rates following harvest and burn treatments;
- Minimum, maximum, mean and standard deviation of crown sizes and plant heights;
- Percent cover per treatment – crown size (area of an ellipsoid);
- Percent seedlings and percent rapid tiller production for treatments;
- Resin score (1-4) and inflorescence score (1-6) counts for all hummocks; and,
- Flowering scores and events.

### Qualitative:

- Active plant growth and plant dormancy and;
- Growth patterns and plant morphology.

The quantitative data were further summarised by examining key variables against time since treatment and climate data. These variables link to plant survival rates, regeneration rates, and modes of regeneration (seedlings and rapid tiller production).

### Linear Model for Plant Growth

The effect of treatment (burn or harvest) and season of treatment (wet or dry season) on growth rates of *T. pungens* hummocks was tested using a multiple linear regression analysis. The author conscripted assistance from Dr Ryan McAllister, a systems research scientist with CSIRO, Ecosystem Sciences, Brisbane to conduct this analysis. The dependent variable in the analysis was the calculated volume of the hummocks, and what was actually examined was the volume of each hummock at each sampling round compared to what the volume of that hummock was prior to the application of the burn or harvest treatment i.e. at sampling time 1 in July 2008 (for dry season burns and harvest) and sampling time 2 in March 2009 (for wet season burns and harvest).

Dummy variables were incorporated to include a range of temporal observations of individual hummocks into the model. For example, where season of treatment was to be incorporated into the analysis, a dummy variable ‘Season’ was used, with wet season treatments taking a 1, and treatments applied in the dry season taking a 0 etc. The use of dummy variables enabled the analysis to account for the temporal dependence that existed between each of the sampled hummocks over time. Hence, the analysis was functionally equivalent to a multi-factor ANOVA (Analysis of Variance), except that it was able to account for dependence of observations through time. Using dummy variables in this way also permitted the inclusion of the control data, as it had a completely different scale to the other treated hummocks (in that the control hummocks were already well established by the start of the experiment, whereas the treated hummocks were re-growing following the application of treatments). The linear model was described as follows:

**Equation 1.** Linear model used to compare data sets.

$$\hat{Y}_i = \beta_0 + \beta_1 C_i + \beta_2 W_i + \beta_3 B_i + \beta_4 d_i + \beta_5 d_i W_i + \beta_6 d_i B_i + \beta_7 d_i W_i B_i + \beta_8 d_i C_i$$

In the model, the intercept  $\beta_0$  shows that an unknown factor accounts for differing rates of recovery over time. The  $\beta$ 's are the estimated coefficients, based on a general linear model with a normal distribution. In the model, C is a dummy variable equal to 1 for the control and 0 otherwise; W is a dummy variable equal to 1 when the treatment occurs in the wet season and 0 when in the dry season; B is a dummy variable equal to 1 when the treatment involves burning and 0 when in treatment involves harvesting; and  $d$  is days since treatment. The model also tested for interactions between time since treatment and season of treatment ( $(\beta d_i W_i)$ ); time since treatment and treatment type (burn or harvest) ( $\beta d_i B_i$ ); time since treatment, season of treatment and type of treatment ( $\beta d_i W_i B_i$ ); and time since treatment and control ( $\beta d_i C_i$ ). Y is estimated hummock volume as a percentage of plot biomass in the pre-treatment period.



## Summary

Employing standard firing techniques followed by variations in mechanical and hand harvesting, and monitoring the impacts these experiments had on spinifex regeneration, this study collected data to test whether spinifex can be sustainably harvested. The methods adopted in this project aimed to augment contemporary *Triodia pungens* knowledge and IEK revival in the study region, in addition to investigating sustainable harvesting practices.

## **Chapter 4**

### **Results: Sustainable Harvesting & Reviving Indigenous Ecological Knowledge**

#### **Introduction**

The aim of this chapter is to describe the key characteristics of *Triodia pungens* from field experiments to provide insight into the ecology of the plant and previous IEK. This chapter is separated into four main sections:

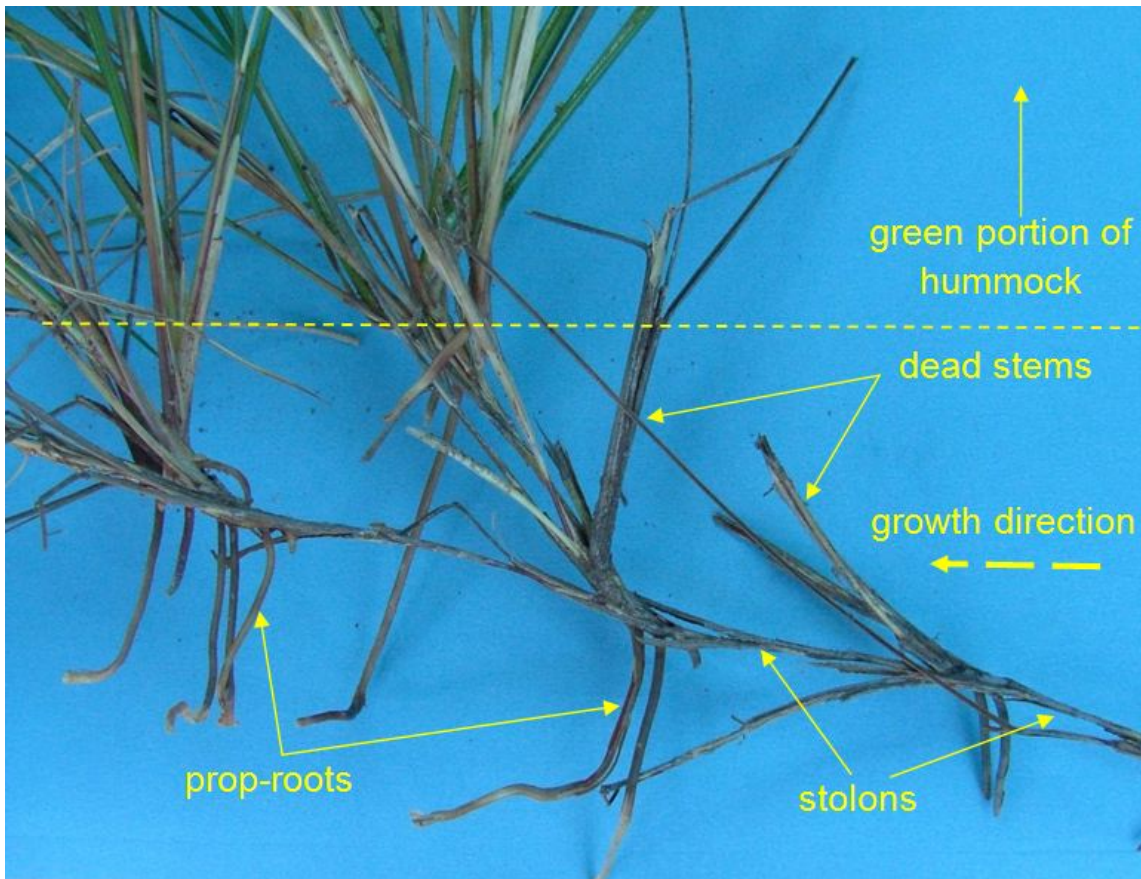
1. Pre-experiment assessment of *T. pungens*;
2. Post-experiment assessment of fire and harvesting affects. The aim is to establish the characteristics of spinifex plants prior to field experiments;
3. Monitoring results and analyses;
4. Analysis of resin cycles and indicators for sustainable harvesting.

Statistical analyses are undertaken to determine plant regeneration characteristics, variations between burn and harvest treatments, and variations in each rotating wet and dry season. These sections are followed by a discussion and summary of the results and analyses.

#### **Pre-experiment Assessment of *Triodia pungens***

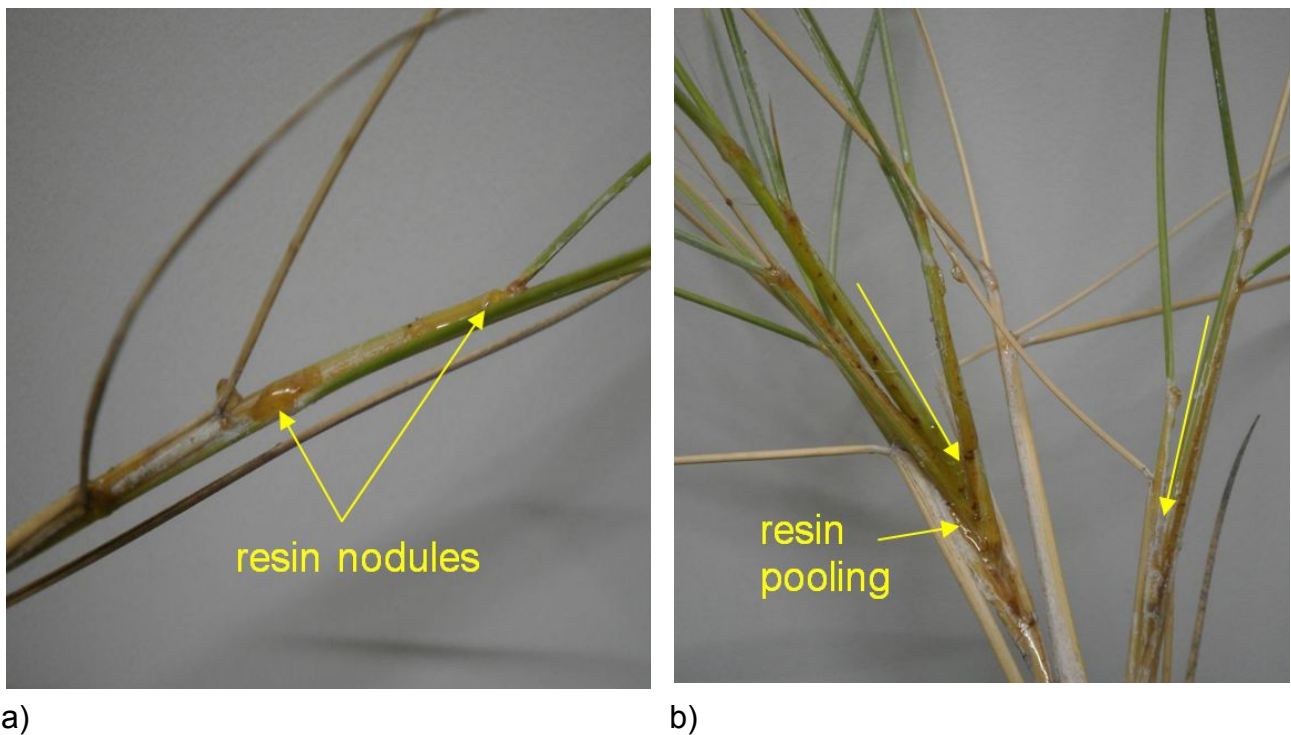
This section examines the pre-treatment (dry and wet season burn and harvest) plant demographics and growth form of *T. pungens* across the study plots. As noted in Chapter 3, these recordings define the growth form and the size characteristics of *T. pungens* with the view that links may be made with spinifex regeneration, i.e. obligate-seeder and resprouters.

An assessment of *Triodia pungens* in the study plots revealed that it has a stoloniferous growth form. Hummocks comprise a network of latent stolons and dead stems and leaf material that becomes greener toward the outer extremities of the plant (Fig. 19). The stolons extend horizontally across the ground to form new nodes, which give rise new prop-roots, stems and leaves at each node (Fig. 19). Large hummocks had many stolons and the centre of the plant retained dead prop-roots and stems.



**Figure 19.** Growth form of *Triodia pungens* showing stolons and prop-roots establishing new stems while the inner stems and plant tissue dies. *Triodia pungens* dies from the central nodes to the outward extremities of the plant.

The U-shaped leaf blade and upward-pointing leaves allows resin to flow down the leaf blade to the base of the leaf and leaf node. During the dry season recordings, hummocks were dry and the network of stems and leaves appeared highly flammable. The amber-coloured resin had coagulated and formed dried nodules of resin along the leaves and stems of hummocks (Fig. 20a). In the wet season however, the stems and leaves were green and actively growing. Resin was most active and flowing to the leaves and stems (Fig. 20b).



**Figure 20.** a) Evidence for amber-coloured resin flowing down the leaves and pooling on the stems below the leaf base. b) resin flowing and pooling at the base of a stems. Resin has a natural flow downwards from the upper leaves and stems.

### Dry Season Plots

At July 2008, a total of 92 mm of rain had fallen in the previous wet season and average monthly temperatures had gradually declined from 41°C to 28°C, resulting in the dry season spinifex plots being in a dormant state. The spinifex leaves were tightly rolled in a cylinder shape, and resin had dried on the leaves and stems of plants. In addition, large numbers of inflorescence stems were present on the hummocks but the glumes were devoid of seed. There was no evidence, such as in the form of seed dispersed within the confines of the hummocks to suggest that this flowering event had produced seed.

Table 4 shows a total of 92 plants were recorded in the Dry Season Harvest (DSH) plots, and 105 plants in the Dry Season Burn (DSB) plots, which is an average of 1.5 to 1.7 plants per square metre, and 13% cover on the DSH plots and 18% cover on the DSB plots. Hummocks reached up to 17 cm high on the DSB plots and 19 cm high on the DSH plots.

**Table 4.** Summary of plant measurements and numbers of hummocks for all monitoring areas at the commencement of the study.

<b>Treatment</b>	<b>Date</b>	<b>Total</b>	<b>Mean Height (cm<sup>2</sup>)</b>	<b>Mean Crown Size (cm<sup>2</sup>)</b>	<b>Cover (%)</b>
<b>DSB</b>	July 2008	105	17	1087	18
<b>DSH</b>	July 2008	92	19	901	13
<b>CONTROL</b>	July 2008	80	19	1569	20
<b>WSB</b>	March 2009	68	30	1945	21
<b>WSH</b>	March 2009	77	33	2397	29
<b>CONTROL</b>	March 2009	82	30	1851	24

#### Wet Season Plots

At March 2009, spinifex hummocks were actively growing, the leaves were open and photosynthesizing, and the hummocks contained large quantities of resin that were actively flowing from the leaves and stems, though the plants had failed to flower. The 774 mm of rain that had fallen between December 2008 and March 2009 saturated the soils. Average temperatures during the wet season had increased from 32° C to 36° C between January and March.

Table 4 provides a summary of wet season hummock characteristics. A total of 68 plants were recorded on the WSB plots, and 77 plants in the WSH plots, which is an average of 2.0 to 2.3 hummocks per square metre, and 21% cover on the WSB plots to 29% cover on the WSH plots. Of these, the mean hummock height for the WSB was 30 cm and 33 cm high for the WSH plots.

#### **Post-experiment assessment of fire and harvesting**

Ten plots were burned and harvested once during the dry season (July 2008), and once during the wet season (March 2009). A summary of the harvesting and burning results are presented in Table 5.

**Table 5.** Summary of the effects of the burn and harvest treatments of spinifex hummocks in the study plots.

Treatment	Mortality ( <i>n</i> )	Survival ( <i>n</i> )	Comments
Dry Season Burn	92	13	All burnt plants killed. Light ash, stained surfaces and charred stems and tillers. Two spinifex ant nests exposed.
Dry Season Harvest (Mechanical Harvesting)	52	40	Plants stripped of leaves and stems. Tillers, stems and leaves remained after mechanical harvesting. Damaged plants survived. Two spinifex Ant nests exposed.
Wet Season Burn	65	3	All plants killed. Unburnt leaves, light ash, stained surfaces, charred stems and tillers. Two spinifex ant nests exposed.
Wet Season Harvest (Hand Harvesting)	73	4	Damaged plants survived. Plants stripped of leaves and stems. Prop-roots, stems, and leaves remained after hand harvesting. One spinifex ant nest exposed.

### Harvesting

Mechanical harvesting of five plots in the dry season (July 2008) partially removed 40% of plants. The Bobcat bucket stripped these hummocks of the leaves and stems (Fig. 21). The 52 plants that were totally removed were killed and did not recover in the next three wet seasons. The hand-harvesting of five plots in March 2009 partially removed four of the 73 plants. The four survivors were stripped of their leaves and stems. The 72 plants that were totally removed were killed and did not recover.



**Figure 21.** Stripped plant after mechanical harvesting. Only a fraction of the plant remained after harvesting. .

### Burning

The dry season fires (July 2008) killed 87% of plants on the five plots. A total of 13 plants survived and were unharmed in the spaces between the hummocks. Scatterings of light ash and ash-stained surfaces, and burned stems and tillers were all that remained after the fires (Fig. 22a). Fires also exposed three spinifex ant (*Ochetellus flavipes*) nests (Fig. 22b).

The wet season fires (March 2009) killed 96% of plants on the five plots. A total of 3 plants survived the fires and were unharmed in the spaces between the hummocks. Scatterings of light ash and ash-stained surfaces, and burned stems and tillers were all that remained after the fires (Fig. 22a). Fires also exposed two spinifex ant (*Ochetellus flavipes*) nests (Fig. 22b). A further result was that the outermost leaves and stems were unburned (Fig. 23). At this time, hummocks were photosynthesising and actively growing and producing resin. This result questioned the flammability of leaves covered in sticky wet resin.





a)



b)

**Figure 22.** Scatterings of ash, ash-stained soil and burnt stems post-burn; and, b) burned spinifex ant (*Ochetellus flavipes*) nest exposed beneath a spinifex hummock post-burn.



**Figure 23.** The unburnt spinifex leaves encircling the location where a plant once grew following firing of one of the Wet Season Burn Plots in March 2009.

Other implications of dry and wet season fire effects included a loss of habitat for the small mammals and reptiles that live within the spinifex hummocks. Reptiles were escaping the dry and wet season fires.



## Monitoring results and analyses

This section is divided into post-burn and post-harvest regeneration and mechanisms for rapid tiller production, total removal versus partial removal of plants, and growth rates, in order to present the evidence for sustainable spinifex-harvesting.

### Post-burn and Post-harvest Regeneration (Seedlings only)

Table 6 shows the total seedling regeneration for all plots. This accounted for 92 % (n=679) of all new plants during the study. These were irrespective of hummocks being killed by fire or harvesting.

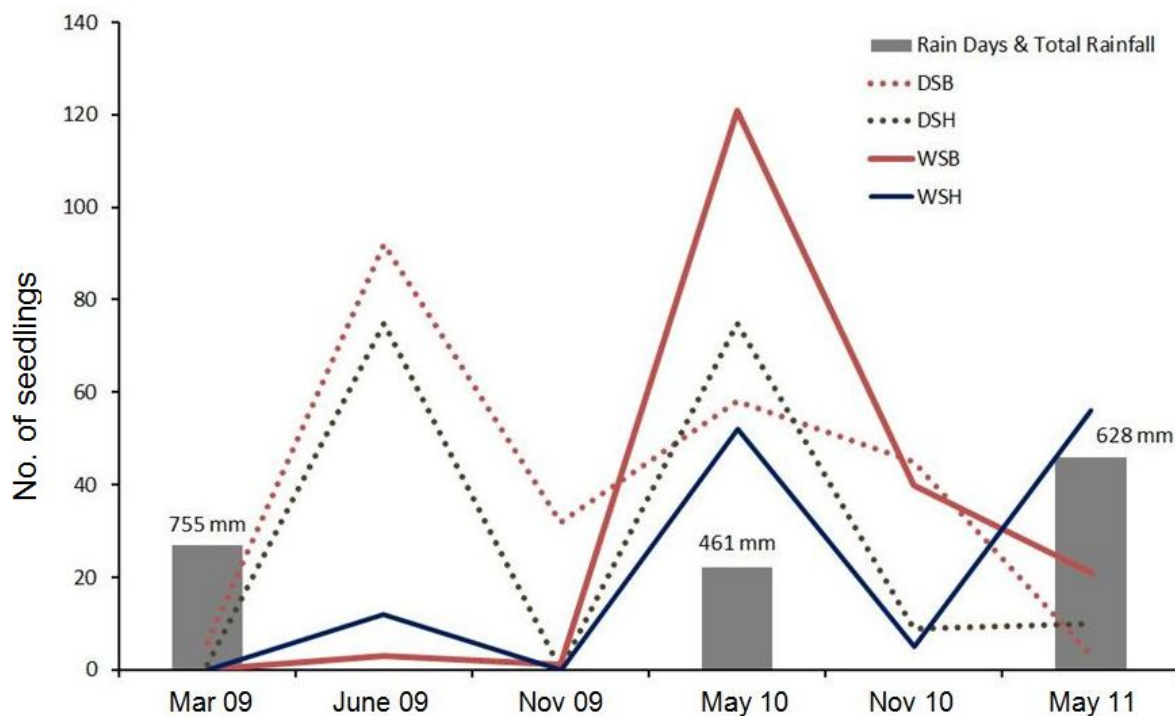
**Table 6.** Burn and harvest regeneration attributes and regeneration strategy for all plots (March 2009 and May 2011).

Experiment	Month and Year	Days	Survivors	Seedlings	Accumulative Total (New Plants)
<i>Dry Season Burn</i>	March 2009	237	13	6	19
	June 2009	337	13	92	124
	Nov 2009	494	13	32	156
	May 2010	654	13	58	214
	Nov 2010	836	13	45	259
	May 2011	1019	13	3	262
<i>Dry Season Harvest</i>	March 2009	237	40	1	41
	June 2009	337	40	75	116
	Nov 2009	494	40	Attrition=30	86
	May 2010	654	40	75	161
	Nov 2010	836	40	9	170
	May 2011	1019	40	10	180
<i>Wet Season Burn</i>	June 2009	100	3	3	6
	Nov 2009	257	3	1	7
	May 2010	417	3	121	128
	Nov 2010	599	3	40	168
	May 2011	782	3	21	189
<i>Wet Season Harvest</i>	June 2009	100	4	12	20
	Nov 2009	257	4	Attrition=8	12
	May 2010	417	4	52	64
	Nov 2010	599	4	5	69
	May 2011	782	4	56	125

The dry-season plots showed a continuous production of seedlings during the study with a complete recovery within 33 months. As expected, sudden increases in seedlings following adequate rainfall in the 2009 and 2010 wet seasons (Table 6 and Fig. 24). Plant attrition also occurred on the dry season and wet season harvest plots during the 2009 dry season (Table 6).

The wet season plots failed to produce seedlings until the next year (2010) (Table 6 and Fig. 24). Seedlings on the wet season burn plots behaved differently to the wet season harvest plots. The wet season had an initial burst of seedlings but numbers continue to reduce over the next year. However, seedlings in the wet season harvest plots had generated in two main burst (May 2010 and May 2011) and the plots had almost totally recovered within 26 months (Table 6 and Fig. 24).

The 2011 wet season coincided with the highest number of rain days ( $n=46$ ) (Table 6 and Fig. 24). However, poor regeneration occurred on all plots except the wet season harvest plots. The latter regenerated in two main bursts of seedlings and the total number of seedlings were much lower in number than the wet season burn plots.



**Figure 24.** The total number of seedlings in each recording period and total wet season rainfall and total number of rain days.

### Partially Removed Plants

The 40 partially-removed plants on the dry season harvest plots regenerated from tillers (Fig. 25). Observations of rapid tiller production from partially-removed hummocks found that tillers emerged in the first (2009) and second wet seasons (2010). Tillers

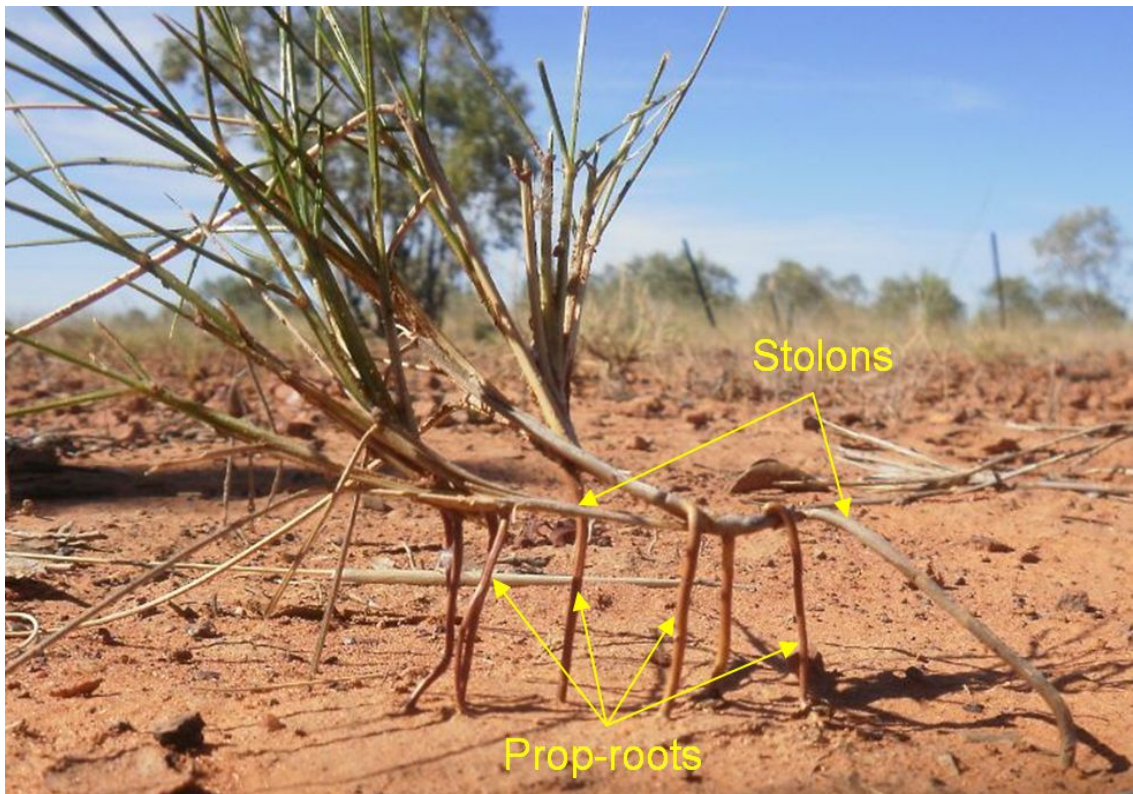
emerge from stark unyielding stems or stolons and extend in a downward direction toward the ground at irregular intervals (Fig. 25). Tillers may emerge from a single new plant node. Most commonly, a single tiller attaches to the ground and supports the new plant (Fig. 26). Stolons and prop-roots (tillers) are irregularly-spaced along a stolon. Tillers will anchor stolons to the ground and stabilise the plant. Other tillers within a similar cluster will be randomly suspended above the ground and eventually die.



**Figure 25.** Example of rapid tiller production on the DSH plot, March 2009. Note the pale reddish colour stem-like parts of the plants are ‘tillers’.

The production of tillers are followed by the production of new stems and leaves, and eventually a new hummock is formed. Stolons and prop-roots (tillers) are irregularly-spaced along a stolon. A single tiller will anchor stolons to the ground and stabilise the plant (Fig. 26).

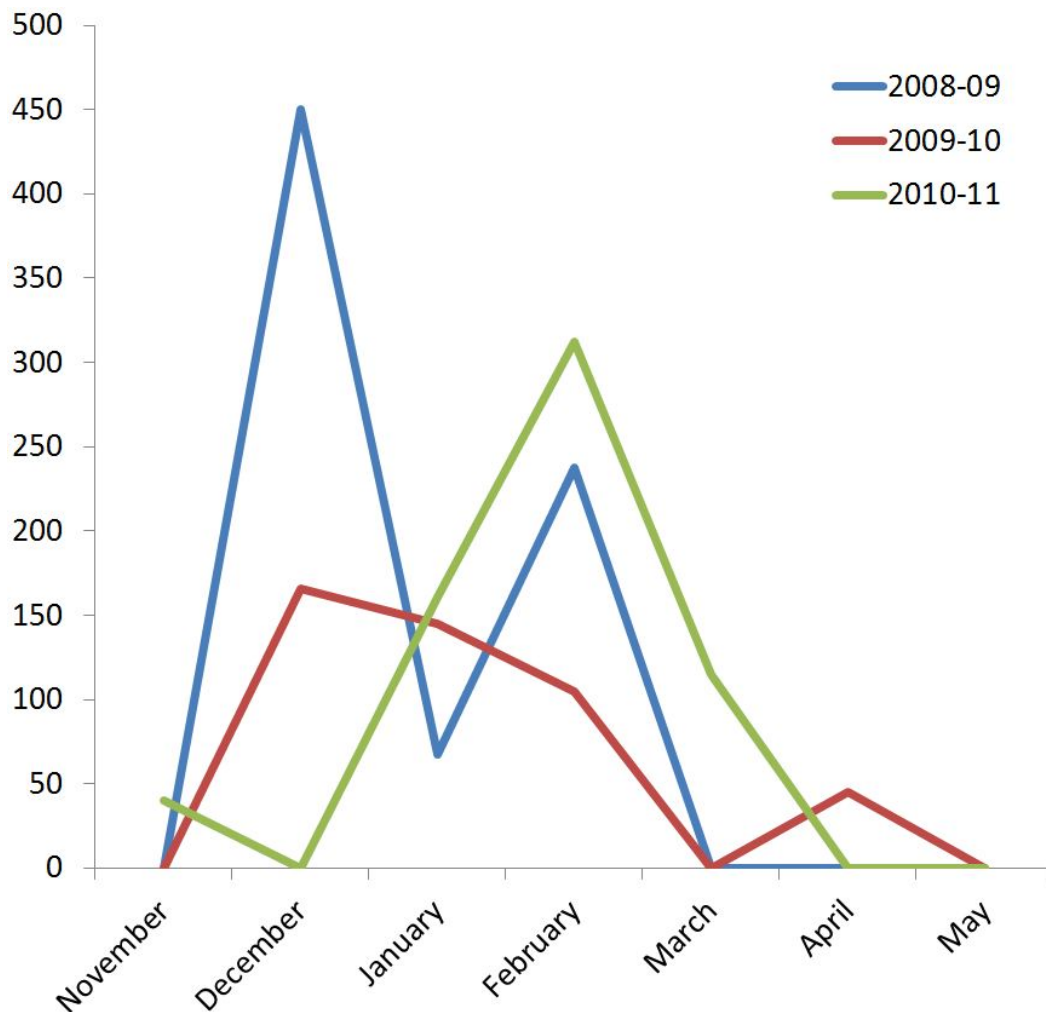




**Figure 26.** Regeneration of spinifex plant after removal by harvesting. Note stolons and cluster of prop-roots (tillers) anchoring the plant to the ground.

### Growth Rates

The majority of rainfall fell between December and May each year (Fig. 27). Although rainfall was higher during the 2009 wet season, spinifex regeneration was actually better during the 2011 wet season when slightly less rain fell but the rain had fallen over a total of 46 rain days (Fig. 27). The 2009 wet season had 27 rain days and 2010 had 22 rain days.



**Figure 27.** Total monthly rainfall (mm) for the three wet seasons during the study.

The results of the multiple regression model are summarised in Table 7 and Table 8. The main findings of the analysis were firstly that control hummocks and days since treatment were strongly significant ( $p = 0.005$  and  $0.013$  respectively). These findings were not unexpected, as controls were untreated and therefore would be expected to have different biomass levels from other hummocks. Moreover, days since treatment would also be expected to be significant, as *T. pungens* in northwest Queensland is strongly stoloniferous and grows back well over time after burning or harvesting.

The second main finding of the analysis was that the season treatment (W) and the burn/harvest treatment (B) were not significant ( $p = 0.876$  and  $0.843$  respectively). However, both of these treatments had significant interactions with the time variable ( $p = 0.013$  ( $d \times W$ );  $p = 0.022$  ( $d \times B$ )). For the interaction between time-since-harvest and

treatment type (burn or harvest), the significant interaction result indicates that the regeneration of the burnt hummocks was different over time compared to the harvested hummocks. In Table 7, while hummocks from both treatments had similar plot biomass at time '0', hummocks that were harvested in the dry season regained biomass at a greater rate than those that were burnt. This trend is supported by the Table 8, which shows the percentage growth rates per day of hummock biomass. For the interaction between time-since-harvest and season, the daily growth rates of the hummocks were faster over time when the harvest or burn treatment occurred in summer compared to winter. Again, this finding is supported by Table 8.

Finally, there was also a significant interaction between season and type of treatment. This indicates that the different treatment types (burn or harvest) do not respond in the same way in both seasons of application. This effect is illustrated in Table 7, where it is seen that both burnt and harvested hummocks responded poorly when the treatment was applied in the wet season. However, when the treatments were applied in the dry season, the harvested hummocks regained biomass much more rapidly than the burnt hummocks.

**Table 7.** Estimated coefficients, based on a general linear model with a normal distribution (analysis completed by Dr. Ryan McAllister, March 2013).

	<b>Coefficients</b>	<b>Standard Error</b>	<b>t Stat</b>	<b>P-value</b>
<b>Intercept</b>	-0.1242	0.29413	-0.42225	0.67353
<b>Control</b>	1.27753	0.45234	2.82428	0.00548
<b>W (Wet/Dry)</b>	0.05198	0.33225	0.15645	0.87592
<b>B (Burn/Harvest)</b>	0.06578	0.33144	0.19846	0.843
<b>Time (days)</b>	0.19%	0.00046	4.06749	8.15762E-05
<b>W*Time</b>	-0.16%	0.00065	-2.51638	0.01306
<b>B*Time</b>	-0.13%	0.00055	-2.30741	0.0226
<b>W*B*Time</b>	0.12%	0.00056	2.08109	0.03937
<b>Control*Time</b>	-0.06%	0.0007	-0.82026	0.41356

**Table 8.** Percentage growth rates per day based on plant biomass (table developed by Dr Ryan McAllister, March 2013).

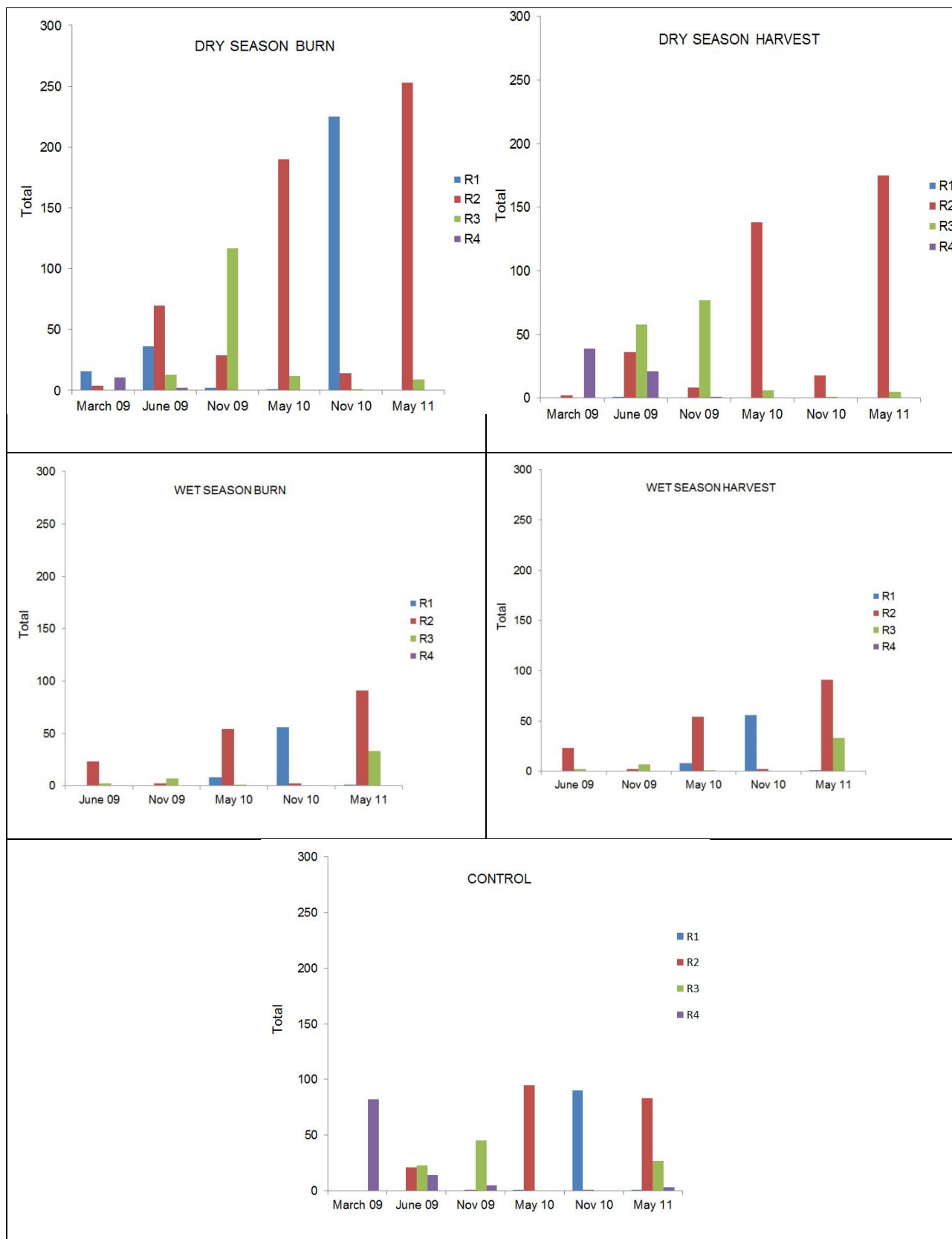
<i>Plots</i>	<i>Percent Growth Per Day</i>
Control	0.13%
Dry Season Burn	0.06%
Dry Season Harvest	0.19%
Wet Season Burn	0.01%
Wet Season Harvest	0.02%

## **Resin and Flowering Cycles and Indicators for Sustainable Harvesting**

### Resin Cycles

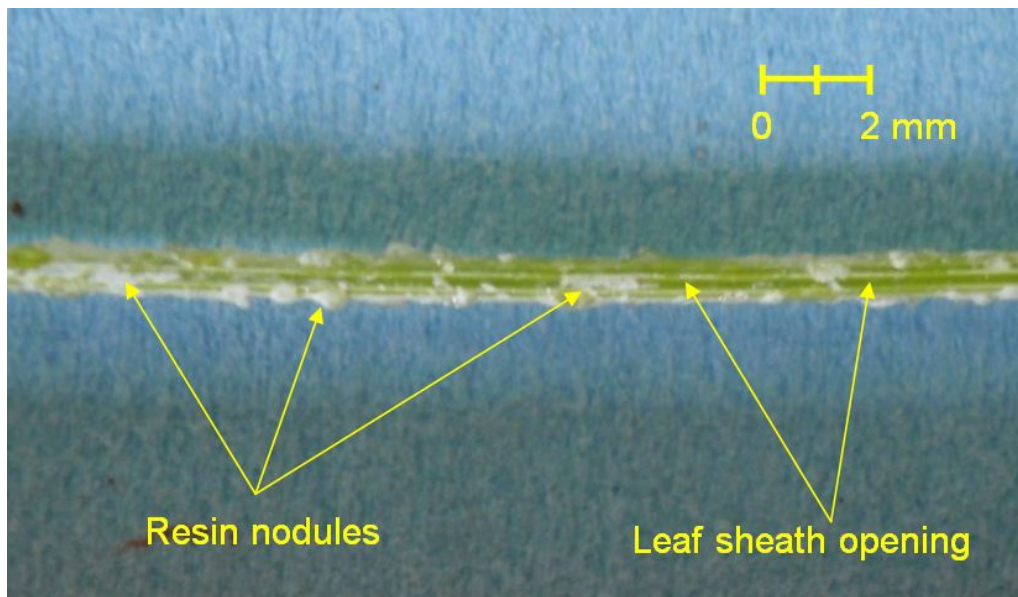
During the plant regeneration phases discussed above, seedlings with nine or more leaves were covered in a thin veneer of resin. Resin production waxed and waned with the changing wet and dry seasons. In the wet season (December to May), resin is highly active, whereas during the dry season, May until November, resin dries and solidifies. During the dry season, resin stickiness ranged from being not so sticky (R1) to mildly sticky (R2) to forming droplets on the leaves and stems (R3) during each wet season (Fig. 28). The continuous flow of resin from the leaves dries on the leaves and stems during the dry season.

An unusual resin production event occurred in November 2009. Resin was observed forming nodules of whitish-coloured resin as droplets, which gave a 'serrated edge' appearance on the leaves (Fig. 29). This included seedlings with nine or more leaves. It is unknown why this occurred and how it relates to resin cycles. A further observation was that the runways and tunnels of *Ochetellus flavipes* (spinifex ant) had a whitish discolouration rather than the normal red-brown colour of the surrounding sediments. It is assumed that this discolouration was from the resin deposits and this had no known effect on the texture or strength of the ant tunnels.



**Figure 28.** Changes in resin scores throughout this study. R1 = Leaves and stems not sticky; R2 = Leaves and stems mildly sticky; R3 = Resin forming droplets; R4 = Resin flowing down stems.





**Figure 29.** Resin excretes from the narrow leaf-sheath opening and deposits along the sheath.

This extraction experiment demonstrated that the dried resin material is contained in the lower stems of the plants. Ten spinifex plants were threshed to make a small cake of resin (Fig. 30). Threshing spinifex hummocks releases the grey resin dust and amber-coloured resin nodules that are contained with the lower stems of the plants. About 220 grams of resin dust, sand particles, and plant matter were extracted. Sieving removes the coarse materials and fines can be made into a small cake of resin. These results and resin cycle monitoring experiment suggests that resin actively flows during the wet season from the upper portions of the hummocks and in turn resin flows to lower leaf nodes and lower stems where it is deposited.



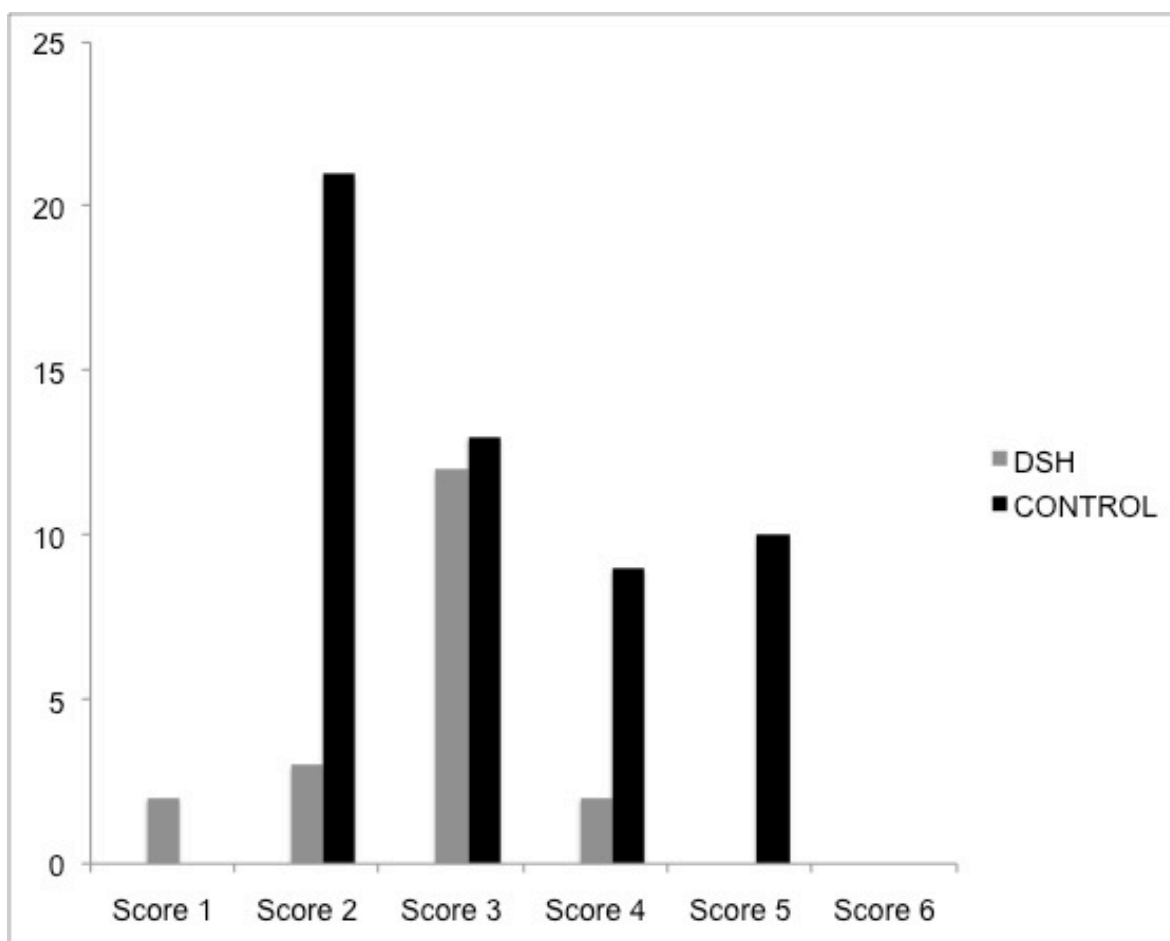
**Figure 30.** A small amount of resin was made from 10 mature *Triodia pungens* plants in November 2009.

This experiment demonstrated that by threshing spinifex during the dry season, resin particles and nodules are easily dislodged from the leaves and stems. These results show that the dry season is an ideal time to obtain useable amounts of resin. During the dry season, these deposits dry on the stems and manifest itself as a film or coating on the lower stems and leaf nodes. It is these areas that are of significance for the development of a resin production strategy.

## Flowering

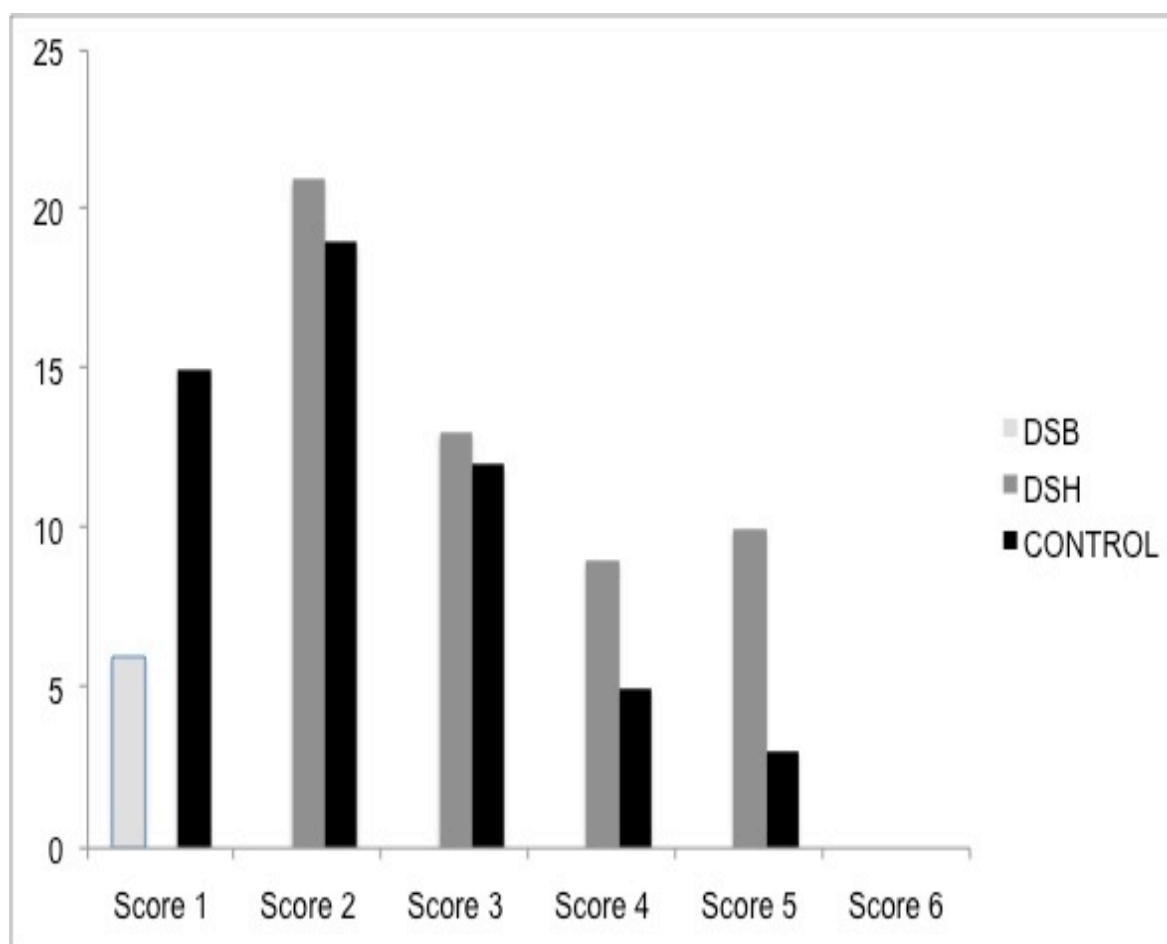
Flowering was absent in the 2009 wet season despite a higher than average rainfall on the study site. It is unclear why the spinifex did not flower in this wet season but it is likely due to inadequate average daily/diurnal temperatures. This needs further investigation. Spinifex did however, flower in the dry season harvest and control plots during the 2010 and 2011 wet seasons (Fig. 31 and Fig. 32). These plots flowered because they had mature plants.

The number of plants that flowered and their relevant scores are presented in each table provided in Figure 31 and Figure 32. The 'score' is a graduated range of values for grading the number of inflorescences produced by an individual hummock after each flowering event.



	DSB	DSH	CONTROL
Score 1	0	2	0
Score 2	0	3	21
Score 3	0	12	13
Score 4	0	2	9
Score 5	0	0	10
Score 6	0	0	0

**Figure 31.** Number of plants that flowered in the dry season harvest, and control plots during the 2010 wet season. Score 1 = 1-3; Score 2 = 4-10; Score 3 = 11-30; Score 4 = 31-100; Score 5 = 101-300; Score 6 = 300-1000.



	DSB	DSH	CONTROL
Score 1	6	0	15
Score 2	0	21	19
Score 3	0	13	12
Score 4	0	9	5
Score 5	0	10	3
Score 6	0	0	0

**Figure 32.** Number of plants that flowered in the dry season burn, dry season harvest, and control plots and their score during the 2011 wet season. Score 1 = 1-3; Score 2 = 4-10; Score 3 = 11-30; Score 4 = 31-100; Score 5 = 101-300; Score 6 = 300-1000.

The dry season harvest plots flowered before all other experimental plots. During the 2011 wet season, the number of inflorescences on the dry season harvest plots increased in number and score from the previous year. The dry season plots also had larger numbers of inflorescence stems than the control plots during the 2011 wet season. From these results it is suggested that younger spinifex plants produce larger numbers of inflorescences. The absence of flowering in the wet season experimental plots suggests that plants were too immature to flower. Therefore the larger-sized plants on the dry season harvest and dry season burn plots suggest that flowering is a strong indicator of plant maturity.

It is unknown how much seed was produced during each major flowering event but it is clear that there are links between flowering events and the maintenance of soil seed-banks. This study also noted that strong correlations occur between flowering and plant maturity. The DSB, WSB, and WSH plots did not flower because these plants were immature. These results indicate that flowering is a strong indicator of plant maturity. It is suggested that flowering is essential for the maintenance of soil seed-banks. Flowering is therefore a primary indicator for selecting plants for harvesting.

## **Discussion**

The aim of this chapter has been to describe the key characteristics of *Triodia pungens* from field experiments to provide insight into the ecology of the plant and previous IEK. The following discussion examines the primary and secondary aims of this thesis by discussing the outcomes of this study.

### **Sustainable Harvesting**

At the outset of this study it was hypothesised that sustainable harvesting was necessary for the development of a commercial harvesting venture that involved bio-engineering of spinifex fibre and resin.

Initial problems considered are the modes of regeneration after treatment. Previous research identified that *T. pungens* regenerates by seedlings, resprouts, and below-ground meristems (leaves and stems emerge from the growing tips of the underlying rootstock) (Chapter 2). Elsewhere in Australia, *T. pungens* regenerated entirely by either seedlings or resprouts, and areas to the north of the Tropic of Capricorn were more likely

to resprout<sup>112</sup>. In addition, Jacobs reported that *T. pungens* would regenerate by rapid tiller production, seedlings and below-ground meristems<sup>113</sup>. The lack of previous spinifex research in this region however, posed questions about *T. pungens* regeneration and whether fire and harvesting would obtain similar results.

The experiments reported here show decisively that spinifex successfully regenerates after mechanical and hand-harvesting—the dry season plots recovered within 33 months and the wet season plots had almost recovered within 26 months. Fire kills spinifex and the ground is covered with a light layer of ash and occasional charred burnt stems and tillers. This study also found that spinifex is harvest-killed following total plant removal. Fire and harvest-killed plants regenerate by seedlings. The recovery of *T. pungens* is similar to what has been described previously by Jacobs<sup>114</sup>, Rice and Westoby<sup>115</sup>, and Felderhof<sup>116</sup>. Complete removal of spinifex by fire or harvesting kills spinifex. The ground remains entirely bare until sufficient wet season rainfall in February each wet season stimulates seedling regeneration. Little if any distinction could be made between seedling regeneration on the fire and harvesting plots. Initially, seedlings are prolific but these numbers reduce over time (three wet seasons).

What is not clear, dependency on soil seed-banks and the known poor seed production in this species, casts doubt over sustainable harvesting if regeneration is totally reliant on this form of regeneration. Because total removal limits regeneration to seedlings only, the total dependence on seed-banks makes this species vulnerable to poor regeneration and unsustainable harvesting practices.

The fact that seedling production was the main strategy for plant regeneration on fire and harvest-killed suggests that the consistencies are biological in their establishment method. Irrespective of how spinifex is removed, these results demonstrate its strong biological traits and ability to recover without heat and smoke. These results suggest that

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<sup>112</sup> Rice, B. and Westoby, M. (1999). Regeneration after fire in *Triodia* R. Br. *Australian Journal of Ecology*. Vol. 24: 567.

<sup>113</sup> Jacobs, S. (1992). Spinifex (*Triodia*, *Plectrachne*, *Symplectrodia* and *Monodia*: *Poaceae*) in Australia. In, Chapman, G. P. (Ed.), *Desertified Grasslands: Their Biology and Management*. Academic Press, London. 55.

<sup>114</sup> *ibid.* 47-62.

<sup>115</sup> Rice, B. and Westoby, M. (1999). Regeneration after fire in *Triodia* R. Br. *Australian Journal of Ecology*. Vol. 24: 563-572.

<sup>116</sup> Felderhof, L. (2007). *The fire patchiness paradigm: a case study in northwest Queensland*. PhD Thesis, James Cook University. 82.

*Triodia pungens* regeneration is driven by rainfall and the rotational wet and dry seasons. These results demonstrate that heat and smoke is not required for seedlings to germinate in this region. The hypothesis that an absence of heat and smoke does not account for plant regeneration.

The major outcome of this study is the partial removal of hummocks by mechanical harvesting. This regeneration strategy is called rapid tiller production and until now little was known about it. This encourages rapid tiller production and maturity within three wet seasons. This regeneration mechanism is not fully understood but tillers are the catalyst for the emergence of stolons, and stems and leaves, and subsequently a new plant. Tillers appeared after the first wet-season and hummock growth continued and eventually the host plant was replaced a new hummock. Tillers emerge from partially-removed hummocks and this in turn produces new stems of leaves, which replaces the host plant within a single wet-season.

This study has identified that rapid tiller production has major implications for developing a sustainable harvesting model for *T. pungens* in this region. The experiments found that the propensity of plant regeneration is related to wet-season rainfall and harvesting techniques, total or partial removal, effects regrowth.

Whilst seedlings is a primary form of regeneration in the study area, for sustainable harvesting it is considered a secondary strategy for plant regeneration. Once established, seedlings will regenerate at similar rates, whether they are located on the fire and harvest plots. It is apparent that seedlings would function to populate the spaces between the larger hummocks and value-add to sustainable spinifex-harvesting. Leaving areas bare for two dry seasons poses long-term environmental risks and ultimately an imbalance in the local ecology.

At the start of this study it was unknown whether spinifex could be sustainably harvested. The experiments conducted here show that spinifex can be harvested sustainably by encouraging new growth from the stems of plants that had been stripped during harvesting, and seedling regeneration would provide a secondary form of spinifex regeneration. For this reason it is important for spinifex to flower and maintain soil-seed banks. The key to sustainable harvesting though is the partial removal of hummocks and encouraging rapid tiller production and thus increased spinifex regrowth rates.

## Indigenous Ecological Knowledge revival

A secondary aim of this study is that sustainable harvesting is dependent on successful resin production and understanding resin cycles. Because Aboriginal people knew when and how to harvest spinifex for resin extraction, understanding resin cycles is important for IEK revival and investigating sustainable spinifex-harvesting. As previously discussed by Jacobs, resin is produced on hot days flowing down the leaves and stems but on cooler days, resin coagulates and cracks to allow gas exchange<sup>117</sup>. The most logical time to extract resin during the cooler days or when resin has dried on the leaves and stems.

As pointed out by Binford, Aboriginal people threshed hummocks to dislodge a quantity of gray dust<sup>118</sup>. The conditions surrounding this event are unknown but the results of this study suggest that these highly-resinous hummocks will produce sufficient quantities of resin after 33 months or three wet seasons. Resin is available in the late dry season after hummocks have matured and set seed. In contrast, it is unlikely that sufficient quantities of resin dust can be extracted during the height of the wet season (February/March). Hummocks that are actively producing sticky resin are unsuitable for harvesting. However, by allowing spinifex to produce resin to collect on the lower stems during the wet season, this encourages maximum resin production.

Toward the end of the dry season (September to November), resin coagulates and dries on the leaves and stems. Resin should be dry and flaking from the plant to produce the grey resin dust described by Binford<sup>119</sup>. It was obvious that dried resin could be more easily dislodged when hummocks were dormant. Resin cycles in the study site support the proportions that selection and harvesting of mature plants late in the dry season (September to November) being an ideal for obtaining maximum quantities of fibre and resin. This outcome and the implications identified above will be discussed in the final chapter.

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<sup>117</sup> Jacobs, S. (1992). Spinifex (*Triodia*, *Plectrachne*, *Symplectrodia* and *Monodia*: *Poaceae*) in Australia. In, Chapman, G. P. (Ed.), *Desertified Grasslands: Their Biology and Management*. Academic Press, London. 55.

<sup>118</sup> Binford, L. R. (1984). An Alyawara day: flour, spinifex gum, and shifting perspectives. *Journal of Anthropological Research*. Vol. 40(1): 164.

<sup>119</sup> *Ibid.* 164



The relationship between maturity and flowering also applies to IEK. It is noted that flowering is a practical marker for knowing when to harvest spinifex. It is anticipated that the appearance of inflorescence stems on hummocks are easily recognisable and may be used in a practical sense by the community. The timing of resin harvesting is interlinked with this marker, but as mentioned above, a minimum of two flowering events is essential for a sustainable industry.

The data collected in this study produce a much clearer understanding of when resin might have been harvested and the findings predict likely elements of resin extraction practices that may have been conducted by the Indjalandji-Dhidhanu people in their cultural traditions. Spinifex hummocks produced adequate amounts of resin and these variables were important for developing a sustainable harvesting model and reinterpreting Indigenous Ecological Knowledge (IEK), which will be discussed in the next chapter.

Understanding regeneration and growth rates in the study area aids in interpreting landscape dynamics and understanding *T. pungens*. Hummocks will return to their pre-treatment sizes within three wet seasons. In addition, in the third wet season, several plants (2–5 plants) will merge together to form a single larger hummock. The crown of hummocks will merge together and form a composite hummock. This suggested that increases the canopy area, cover, and biomass in an area. This has implications for sustainable harvesting and resin production rates.

## Summary

This chapter presented the results of spinifex-harvesting field experiments. The aim was to investigate sustainable spinifex-harvesting practices and IEK revival in the Camooweal region of Queensland. The experiments demonstrate that *T. pungens* can be sustainably harvested and data may be transcribed into useable knowledge. *Triodia pungens* regenerates in response to rainfall and harvest and fire-killed spinifex regenerates by seedlings only. Whereas partially removed spinifex hummocks, of which several stems and leaves survive, spinifex will regenerate by rapid tiller production and this favours greater growth rates and sooner plant maturity (plants flower sooner). Resin production and the timing of harvesting is a product of wet and dry season cycles. The wet season encourages resin production and the dry season cause resin to coagulate and dry on the stems and leaves.

## **Chapter 5**

### **Spinifex: Towards a Sustainable Harvesting Model and Indigenous Ecological Knowledge Revival**

#### **Introduction**

The aim of this chapter is to integrate the information presented in preceding chapters to suggest how spinifex can be sustainably managed to inform potential commercial applications involving spinifex harvesting in Aboriginal communities. The primary aim of this thesis has been to develop an understanding of spinifex ecology such that harvesting practices and knowledge of spinifex resin-cycles and flowering can underpin future commercial applications of spinifex and Indigenous ecological knowledge revival in the Camooweal region of Queensland. At the outset, little guidance was available to Aboriginal people wanting to harvest spinifex at a commercial scale. The questions of when, how often, and how much spinifex should they harvest and will it be sustainable, are all critical to a successful spinifex industry.

The major issue for this study was addressing how spinifex might respond to harvesting, and whether the absence of heat and smoke would affect regeneration (as these factors are known to be a necessary stimulant for the seed germination of many native Australian plants). The null hypothesis was that spinifex fails to recover after harvesting treatments, indicating that it requires heat and smoke to successfully regenerate. Rejection of the null hypothesis supports successful spinifex regeneration and the development of a sustainable harvesting in the study area.

This synthesis provides an overview of sustainable spinifex harvesting and makes recommendations for management strategies in this region. Such a strategic approach would allow sustainable spinifex harvesting goals and the development of knowledge about this species. This chapter concludes by taking into account the directions for future research to improve our understanding of *T. pungens* and to foster the involvement of Indjalandji-Dhidanu people in future ventures.

## Research Approach

As noted in Chapters 1 and 2, prior to this study there had been no research into the effects of harvesting on *T. pungens*. However, several spinifex fire regeneration studies had yielded a model for spinifex regeneration suggesting that fire is a necessary tool for maintaining healthy spinifex ecosystems. This study used monitoring techniques to examine how spinifex reacted to the effects of fire and harvesting treatments during both the dry and wet seasons. The effects of fire and harvesting in the dry and wet seasons were investigated by analysing daily growth rates and forms of spinifex regeneration. Through this, it was possible to determine whether spinifex could be sustainably harvested.

A classification of resin cycles and flowering characteristics helped to explore resin yields and the potential for flowering and thus maintaining soil seed-banks. This assumed spinifex would produce resin and fibre, and flower in response to adequate amounts of wet season rainfall each year. A resin production experiment complemented the main field study by extracting resin from a small number of mature plants. This supported the monitoring of spinifex throughout the study.

A second aspect of this study was the interpretation of scientific data to understand Indigenous ecological knowledge. Initially this seemed an onerous task because of the lack of previous research, but it was soon realised that by making links between scientific data and Indigenous knowledge, this is an important first step for developing Indigenous knowledge and a sustainable spinifex harvesting industry. The sustainable harvesting model places confidence in extrapolating spinifex data for the development of Indigenous knowledge.

The results were interpreted in regards to sustainable spinifex harvesting potential. Suggestions were made about spinifex harvesting techniques (how to mechanically harvest spinifex and at what time of year) and field monitoring procedures to ensure spinifex areas can be managed in the long term. The combined results helped to gain an insight into a potential sustainable spinifex harvesting industry.

## Summary of Results

### Regeneration Patterns

The prediction was that spinifex is killed by fire and that regeneration would occur only via seedlings<sup>120</sup>. This study found that spinifex will regenerate simultaneously by both seedlings and sprout by rapid tiller production during the growing season in response to adequate amounts of wet season rainfall.

Large numbers of seedlings germinated in the post-fire and post-harvest plots and seedling numbers continued to increase each wet season thereafter. Seedling emergence was initially high after treatment but as hummock size increased and ground cover lessened, there was a marked decrease in seedlings numbers. Similar results were replicated in the harvesting plots, particularly in those plots where the hummocks were totally removed during harvesting.

An additional form of regeneration results from the partial removal of hummocks during harvesting. New tillers emerge from a host plant to produce new mature hummock within 33 months. The most striking feature of this form of regeneration is that plants grow at much higher rates than those produced by seedling germination, and hummocks will flower and set seed within three wet seasons. It is clear that this form of regeneration is preferable for a sustainable spinifex harvesting.

The successful regeneration of harvest plots and multiple regeneration phases in all harvest plots throughout the duration of the study showed that an absence of heat and smoke has no impact on spinifex regeneration. Whilst it is possible that heat and smoke from neighboring burn plots could have affected the harvest plots, seedling emergence in subsequent wet seasons discounts this phenomenon. These results demonstrate commonalities in the post-burn and post-harvesting regeneration of spinifex—factors such as the absence of heat and smoke during harvesting did not appear to impact on subsequent seedling germination.

Clearly, if seedlings had not emerged on all of the harvest plots, fire would be a necessary stimulant for spinifex regeneration in the study area. This suggests strongly that spinifex harvesting could be undertaken in a sustainable fashion providing soil seed-banks

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<sup>120</sup> Rice, B. and Westoby, M. (1999). Regeneration after fire in *Triodia* R. Br. *Australian Journal of Ecology*. Vol. 24: 564.

are maintained; this can be achieved by allowing spinifex plants to flower and set seed before they are harvested.

## Growing Season

The growing season occurs between December and May each year, which coincides with the consistent summer rainfall. Under ideal rainfall and temperature conditions, seedlings and tillers will emerge and is able to reach maturity within at least three growing seasons. The growing season continues until the middle of the dry season, e.g. June, when soil moisture and daily average temperatures will significantly decline.

Flowering events, which correspond to the growing season, also occur during the wet season. This study showed that mature spinifex hummocks flowered during the 2010 and 2011 wet seasons but inexplicably hummocks failed to flower during the 2009 wet season despite receiving 880 mm of rain. Whilst the reason for this was not investigated, it is hypothesised that average daily temperatures will affect spinifex flowering. That is, spinifex hummocks require ideal temperature conditions in order for spinifex to flower. However, this needs further investigation.

In summary, the consistent summer rainfall of northern Queensland supports the development of a successful spinifex harvesting industry in this region. When compared to other drier regions of Australia where rainfall is variable in amount and timing, northern Queensland offers a stable growing environment and window of opportunity for spinifex to recover from harvesting.

## Seed Banks and Plant Maturity

Flowering and seed-setting are important elements of securing maximum spinifex regeneration, and thus maintaining the health of the soil seed-bank is vital. Spinifex flowers set seed, often producing only low percentages of seed during such events<sup>121</sup>, shortly after a flowering, with the inflorescence stems remaining on the plant for up to two years<sup>122</sup>. This study has shown that flowering is critical to maintain the viability of the soil

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<sup>121</sup> Jacobs, S. (1992). Spinifex (*Triodia*, *Plectrachne*, *Symplectrodia* and *Monodia*: *Poaceae*) in Australia. In, Chapman, G. P. (Ed.), *Desertified Grasslands: Their Biology and Management*. Academic Press, London. 57.

<sup>122</sup> *ibid.* 57.

seed-bank, in turn allowing seedlings to populate areas between hummocks in subsequent wet seasons.

This study also found that flowering provides an observational marker to indicate when a plant has reached maturity, and thus for assisting in making an assessment as to when spinifex might be ready to be harvested. The data indicate that crown size and flowering are indicative of the transition to plant maturity. It is identified that one or more flowering events suggest spinifex hummocks have reached maturity. This also offers greater replenishment of soil seed-banks, and assurance that these seed-banks can support seedling production thereafter.

### **Resin and Fibre Production**

The small experiment conducted in the study demonstrated that *Triodia pungens* cycles between wet sticky resin actively flowing from the leaves in the wet season (December to May), to resin drying on the leaves and stems toward the end of the dry season (June to November). During the wet season, spinifex produces adequate quantities of resin, which flows down the leaves and to the stems. This provides a deposit of resin that can be easily dislodged during the middle to late dry season (July to November). This is considered the most suitable time to harvest resin from stems and leaves of hummocks. The wet season (December to May) however, is unsuitable for resin extraction because the resin actively flowing from the leaves and its consistency is wet and very sticky. These results suggest that resin extraction is an annual event that can be conducted over several months of the dry season each year. However, developing other resin techniques may help to resolve resin extraction during the wet season.

Memmott *et al.* suggested that spinifex fibre could be used to develop new building products<sup>123</sup>. Whilst this study did not directly address fibre production, examining changes in hummock size over time aided in the development of a database that could ultimately be linked to practical development of fibre production. Applying techniques to capture biomass and fibre production may be conceptually useful for managers who are attempting to select suitable harvesting areas and developing sustainable harvesting practices.

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<sup>123</sup> Memmott, P., Schmidt, S., Master, D., Fensham, R., and Hyde, R. (2008). *Towards Novel Biomimetic Building Materials: Evaluating Aboriginal & Western Scientific Knowledge of Spinifex Grasses*. Aboriginal Environments Research Centre, The University of Queensland, St Lucia, Queensland.

## **Sustainable Harvesting Model**

Part of the solution to developing a sustainable spinifex-harvesting methodology rests with the development of an effective spinifex assessment strategy for maximising resin and fibre production, and the invention of harvesting equipment and techniques that encourage rapid tiller regeneration. A sustainable harvesting model for the study area should:

1. Assess and understand links between hummock size and resin and fibre production;
2. Carry out harvesting during the late dry season (September to November) to maximize resin yield;
3. Partially remove plants to stimulate above-ground meristematic regeneration;
4. Allow at least three or four wet seasons to pass before re-harvesting spinifex in the same area. This methodology aims to encourage flowering events to maintain soil seed-banks and invigorate seedling regeneration in the intervening wet seasons.

Each of these four aspects is discussed in turn below.

### Strategic Assessment of Hummocks for Maximum Resin and Fibre Production

A strategic spinifex assessment approach should focus on understanding links between hummock size and resin and fibre yields. For instance, hummocks with many stems and active resin-producing leaves will inevitably maximise resin and fibre production and produce higher crop yields. One issue to consider though is that spinifex dies from the centre outwards and leaves and stems in the centre of the plant are unsuitable for resin and fibre production. To overcome this issue, it is important to maintain a database of time since harvest (or a burn) and hummock sizes and percentage of dead fibre to maximise resin and fibre production.

### Timing of Harvest for Maximum Resin and Fibre Production

These analyses determined that late dry season (September to November) harvesting is the ideal time to harvest spinifex to maximise resin yields. At this time of year, resin has generally dried on the leaves and stems of hummocks and threshing techniques can easily dislodge resin dust. On the other hand, it is impossible to dislodge

sticky resin from hummocks during wet season unless other techniques are developed (e.g. chemical).

Hummock size variation affects resin and fibre production and therefore requires a monitoring management strategy. These differences are measurable and this could be plotted on a continuum of resin and fibre production to focus on understanding such production as a management and business goal. Understanding these differences in resin production is important for developing a sustainable harvesting industry for Indigenous communities.

### Harvesting Technique

The primary requirements for developing a sustainable harvesting industry in north-west Queensland are that harvesting occurs in the dry season, by partially removing each hummock rather than cutting them off fully at ground level. Carefully selecting mature resinous plants using a strategic assessment program that includes an evaluation of plant maturity (i.e. assessing the number of inflorescence stems on plants) will be vital to ensuring a successful and sustainable spinifex-harvesting industry. However, it does not suggest that there is an optimal number of plants required for obtaining commercial quantities of fibre or resin. Development of monitoring programs could help to understand this better.

This study has demonstrated that an alternative regeneration trait is encouraged by partially removing hummocks, as opposed to complete removal of plants. It is recommended that no more than 60% of a hummock should be removed during harvesting, which would leave the remaining plant with sufficient quantities of tillers, stems and leaves to survive and reproduce by rapid tiller production.

In other words, the partial removal of spinifex hummocks by harvesting allows the plant to regenerate from the remaining host plant. Once hummocks are established, the new stems and leaves are thereafter able to grow into a larger plant, which eventually takes the place of the initial host plant.

Therefore, a successful harvesting procedure will require development of techniques for partial removal of hummocks, as opposed to their total removal. The upshot is that the greater percentage of stems and leaves encourages rapid tiller production from



the host plant and subsequently higher re-growth rates and sooner plant maturity. The exact harvesting technique that can achieve these outcomes requires further investigation.

### Sustainable Harvesting Actions

Between harvesting events, a time period of at least three to four wet seasons should be allowed to pass, during which the plant should be allowed to flower at least twice. This will ensure plants have sufficient time to sexually reproduce and set seed, thereby replenishing soil seed-stocks. This is important for encouraging seedling germination between the hummocks to promote ecological diversity and ensure sustainability of the process.

Hummocks may contain inflorescence stems from previous flowering events, so careful assessment of these traits will be critical to identifying suitable spinifex patches to harvest. The latter will be determined by monitoring the number of flowering events and seed production. In this instance, rapid tiller production and seed production will be essential for maintaining a sustainable harvesting program and managing the long-term viability of a resin and fibre production industry.

### **Indigenous Ecological Knowledge and Scientific Research**

A great deal of specific and intricate knowledge of spinifex existed in the study area but it was not until contemporary studies such as the broader ARC spinifex project (described in Chapter 1), that the gaps in this knowledge base were fully realised, which highlights the importance of Indigenous knowledge and its retention in the community. As discussed by Memmott *et al.*, understanding the ecology of *T. pungens* is vital if this species is to become a viable industry that can contribute to economic development in remote Indigenous communities<sup>124</sup>. Memmott *et al.* described the benefits that arise from linking ethnographic and ecological research with building science to create new technologies<sup>125</sup>. However, the lack of ethnographic research in the study region, combined with limited ecological and traditional IEK about *T. pungens*, are limiting factors to determining ways of potentially utilising spinifex. It is important to recognise how Indigenous knowledge may contribute to contemporary spinifex markets. Finally,

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<sup>124</sup> Memmott, P., Hyde, R., and O'Rourke, T. (2009). Biomimetic Theory and Building Technology: Use of Aboriginal and Scientific Knowledge of Spinifex Grass. *Architectural Science Review*. Vol. 52(2): 117-125.

<sup>125</sup> *ibid.* 117.

establishing links between science and Indigenous ecological knowledge are an important first step in developing partnerships between Indigenous and non-Indigenous people.

This study involved a literature review to bring together existing knowledge about *T. pungens* and to carry out an experimental post-burn and post-harvest field study. The literature review identified that ethnographers overlooked how Aboriginal people examined the field characteristics of spinifex and why they chose specific plants for resin extraction<sup>126,127</sup>. It is possible that only senior Aboriginal men and women held this knowledge and it appeared that ethnographers did not consider that this information was important.

Further, this study shows that science can obtain knowledge of spinifex use by examining and interpreting its characteristics. However, consultation with the Indjalandji-Dhidhanu community is crucial to ensure that scientists develop culturally-appropriate harvesting methods in collaboration with the community. This will be important for selecting appropriate spinifex-harvesting sites, developing harvesting tools and techniques, and implementing a sustainable spinifex harvesting industry.

## Other Implications

Any harvesting method involving the severing of plants at ground level renders the ground bare, lessens spinifex regrowth rates, and heightens wind and water erosion risks, ultimately for no additional benefit. To overcome this issue, stands of larger hummocks will reduce the amount of bare ground and promote erosion control and ecological diversity, similar to a patch-burning strategy but on a much smaller scale. Another concern is heightening the risk of competition by introduced species, e.g. *Cenchrus ciliaris*, that may reduce the amount of ground cover and prevent opportunities for spinifex to reproduce. This supports the need to maintain hummock size diversity throughout harvested areas.

## Future Research

The major task ahead is to commence pilot commercial harvesting and continue to build a database of spinifex-harvesting yields and regeneration results. Resin and fibre production will vary according to plant size and the leaf area; the smaller the hummock,

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<sup>126</sup> For example, Binford, L. R. (1984). An Alyawara day: flour, spinifex gum, and shifting perspectives. *Journal of Anthropological Research*. Vol. 40(1): 157-182.

<sup>127</sup> Latz P. (2004). *Bushfires and Bushtucker. Aboriginal Plant Use in Central Australia*. Institute for Aboriginal Development Press Alice Springs, Northern Territory. 290-293.

the lower the resin and fibre production. The amount of resin and fibre that is produced per hummock is currently unknown and needs further investigation. While this study developed some understanding of *T. pungens* in the northwest Queensland region, major gaps remain in our understanding of the ecology of this species. Research is required to develop a harvesting technology that efficiently removes hummocks and thereby promoting effective spinifex regeneration. The medium and long-term aims would be to understand how *T. pungens* reacts to harvesting over time. One such issue is the strong association between dry season harvesting and rapid tiller production. But how this might be achieved in a practical sense needs further investigation. Further, more research could unfold the science surrounding rapid tiller production as no such research had previously identified this form of regeneration in spinifex communities. Finally, the impacts of harvesting on non-spinifex species need further investigation.

## Conclusion

The experimental approach used in this study has contributed to developing an understanding as to whether, and how, spinifex may be sustainably harvested in the study region. From the field tests, it is clear that spinifex regenerates over several years following harvesting and preliminary recommendations have been made as to how spinifex might be sustainably harvested.

Through monitoring post-harvesting and post-burn recovery of spinifex this study has improved our knowledge and understanding of this plant within Indjalandji-Dhidanu lands. By examining the regeneration of plants after fire events and harvesting in both the wet and dry seasons, it was revealed there was continuity of above-ground meristematic regeneration following partial removal of plants in the dry season. In comparison to the other treatments, this form of harvesting led to increased levels of plant regeneration, maturity (flowering) and resin production. These findings are critical for instigating sustainable harvesting and land management practices for *T. pungens* on Indjalandji-Dhidanu lands. A challenge in the future will be to understand more fully the diversity and complexity of *T. pungens* and other species in the genus. Future research will provide more accurate ecological datasets and may also have implications for how Aboriginal communities obtain more knowledge of spinifex and become more actively involved in monitoring and managing a sustainable harvesting industry in the region.

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